The Journal of Thoracic Surgery

VOL. 23 JUNE, 1952 No. 6

Original Communications

THE PERIVASCULAR SPACE OF THE PULMONARY VESSELS

AN ANATOMIC DEMONSTRATION*

ALFRED M. TOCKER, M.D., AND HIRAM T. LANGSTON, M.D.
DETROIT, MICH.

IT IS generally conceded that a cleavage plane exists around the pulmonary vessels. Under certain pathologic conditions, this potential perivascular space may be converted into a very real and actual space. Escape of air in several clinical conditions, such as pulmonary interstitial emphysema, into and along these perivascular channels from alveoli which are based along its margins has been postulated and demonstrated by several investigators.[1, 2] Macklin[2] reported the observation of air bubbles in the pulmonic arterial and venous vascular sheaths following intratracheal introduction of air under pressure into the lungs, and noted that the air often found its way into the opposite lung, as well as into the mediastinum. Similar observations are reported by Joannides and Tsoulos.[1] In the isolation of pulmonary blood vessels for ligation, limited sectional demonstrations of this cleavage plane are easily exhibited. However, although textbooks generally mention the existence of a fibrous sheath enclosing vessels, actual anatomic demonstration of this space has been lacking, and there is a paucity of information concerning the peripheral and central extent and relations of this cleavage plane.

We have endeavored to demonstrate this pulmonary perivascular space in the dog by gross, microscopic, and roentgenographic methods in order to determine the relations of this space to the vascular trunks and arborizations within the lung as well as its central relations to the pericardium.

METHOD

The perivascular space was entered at the hilum by blunt dissection through as small an opening as possible, and identified by the fact that not until the perivascular space was entered did separation along a cleavage plane by blunt dissection occur with ease.

A small length of polyethylene tubing of a diameter sufficient to permit a blunted No. 18 needle to fit very snugly into its lumen at one end was introduced into the perivascular space. The tube was secured by placing a ligature tightly around the vessel, compressing the tubing between the outer wall of the perivascular space and the wall of the enclosed vessel

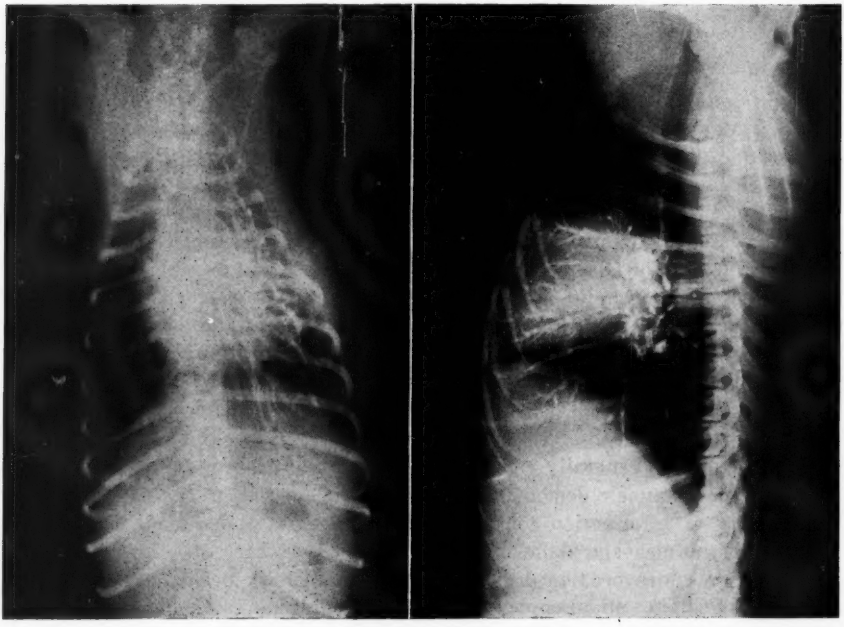
From the Department of Surgery, Wayne University College of Medicine, and the Thoracic Surgery Service, Herman Kiefer Hospital, Detroit, Michigan.

Received for publication Nov. 15, 1951.

*An exhibit of this anatomic demonstration of the pulmonary perivascular system was presented at the meeting of The American Association of Anatomists in Detroit, Mich., in March, 1951.

in such a manner as to exclude the opening through which the tubing had been introduced. Ten to 20 per cent bismuth oxychloride (the less concentrated solution being used in the living animals) was injected under moderate pressure through the polyethylene tube into the closed space thus created.

While a tubing of smaller diameter might have been preferable, the injected radiopaque solution was forced through even the No. 18 needle with difficulty, a 50 c.c. syringe being used to permit the application of moderate force. The nature of the bismuth oxychloride solution made it possible to observe the course of the injection grossly as it dissected its way along the perivascular space, and secure roentgenographic demonstrations of the extent and pattern of its spread, as well as microscopic sections showing the relation of the injected material to the lung structures and vessel wall.



A. *B.*

Fig. 1.—Anteroposterior and lateral roentgenograms of a living dog taken five days after left unilateral injection of pulmonary artery demonstrating ipsilateral and contralateral peri-arterial spaces.

In heart-lung preparations removed en masse, and in living animals in which peripheral and central injections were made, the ligature was first passed through a small rubber ball approximately 0.5 cm. in diameter, which was then placed behind the vessel after the artery or vein had been bluntly dissected free of the surrounding tissues, care being taken to stay well outside of the perivascular space. The rubber ball, upon tying this ligature, compressed the tissues without harming the vessel wall, and could easily be released to permit redirecting of the tubing in the perivascular space into the opposite direction for further injection. Due to mechanical difficulties involved in some of the injections, particularly in those of the veins of individual lung specimens, the larger tributaries rather than the main pulmonary vessels were injected individually.

Injection was continued in each direction until the pressure of the fluid in the perivascular space caused marked bulging of the surrounding wall, until leakage occurred, or until

the injected solution could be seen well out around the small vessels in the periphery of the lung.

Using individual right- and left-lung specimens, injections were made to demonstrate the following perivascular spaces peripherally on each side: (1) inferior pulmonary vein, (2) superior pulmonary vein, (3) inferior and superior pulmonary veins, (4) pulmonary artery, and (5) all vessels.

Using individual heart-lung preparations removed intact en masse, injections were made to demonstrate the perivascular spaces peripherally and centrally as follows: (1) left inferior pulmonary vein, (2) left superior pulmonary vein, (3) left pulmonary artery, (4) right inferior pulmonary vein, (5) right superior pulmonary vein, and (6) right pulmonary artery.

Using living animals, injections were made to demonstrate the perivascular spaces as follows: (Dog No. 1) left inferior pulmonary vein, peripherally; (Dog No. 2) left superior pulmonary vein, peripherally; (Dog No. 3) left inferior and superior pulmonary veins, peripherally; (Dogs No. 4 and No. 5) left inferior pulmonary vein, peripherally and centrally; (Dogs No. 6 and No. 7) left superior pulmonary vein, peripherally and centrally; (Dogs No. 8, No. 9, No. 10, No. 11, No. 12, and No. 13) left pulmonary artery, peripherally and centrally.

Fig. 2.—Peripheral and central injection of inferior pulmonary vein at point marked by arrow, demonstrating contralateral inferior pulmonary vein and ipsilateral superior pulmonary vein.

As a corollary study, the lungs of four heart-lung specimens were inflated by intratracheal insufflation under pressure. In two specimens in which air appeared in the perivascular spaces and traveled centrally into the hilar region, the space created by the passage of air along the vessels was injected with bismuth oxychloride solution and studied microscopically.

EXPERIMENTAL OBSERVATIONS

All peripheral injections were made with comparative ease. Roentgenograms taken with the lungs inflated revealed the existence of a continuous cleavage plane around the most distal branches and tributaries of all the pulmonary vessels (Figs. 1 and 2). Microscopic sections of the injected tissues revealed the injections to have entered a discrete perivascular space, closely following the most minute branchings of the vessels (Figs. 3, 4, and 5).

Injections directed centrally into the arterial perivascular space of two living dogs resulted in the solution breaking into the mediastinum. However, in two of the dogs the perivascular space of the main pulmonary artery as well as that of the contralateral vessel was clearly shown on roentgenograms taken immediately and several days after injection (Fig. 1). Similar findings resulted from the injections around the arteries of the heart-lung preparations. Careful examination revealed no evidence of the injected solution within the blood vessels.

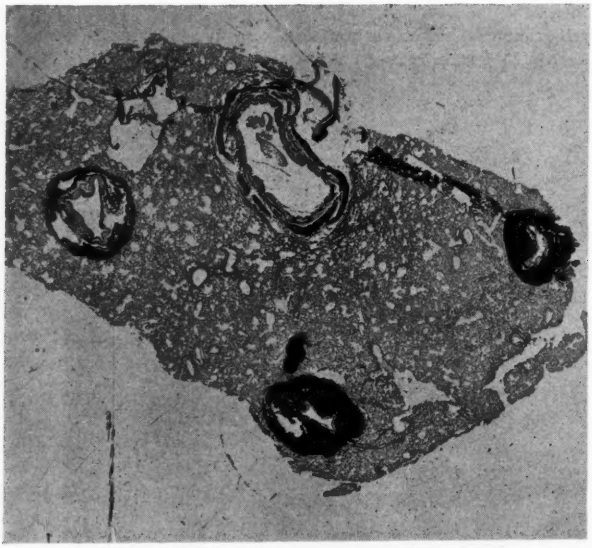


Fig 3.—Low-power field demonstrating bismuth mass in perivascular spaces.

Injections centrally into the perivascular space of the pulmonary veins were consistently unsuccessful in the living animals. In the heart-lung preparations these injections, occasionally accomplished with comparative ease, often required repeated trials. With the pericardial sac opened, it was noted that the injections often resulted in the solution breaking through the serous pericardial covering of the left atrium at several points. By plugging these several leaks as they occurred by placing pressure over this region with our fingers, the solution could be forced beyond and eventually reached the contralateral perivascular spaces, at which time there was a distinct decrease in the resistance to the injection. Central injection of the perivascular space of one pulmonary vein in several specimens resulted in the spread of the solution to the other ipsilateral vein as well as to the contralateral veins (Fig. 2).

Microscopic slides made following injection of the perivascular space created by the passage of air during intratracheal insufflation under pressure of two heart-lung preparations showed the solution to be in a perivascular space similar in all respects to those studied by the above methods.

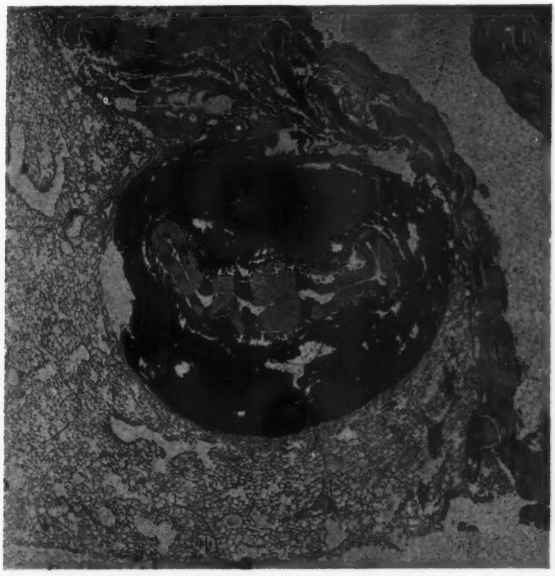


Fig. 4.—Periarterial injection.

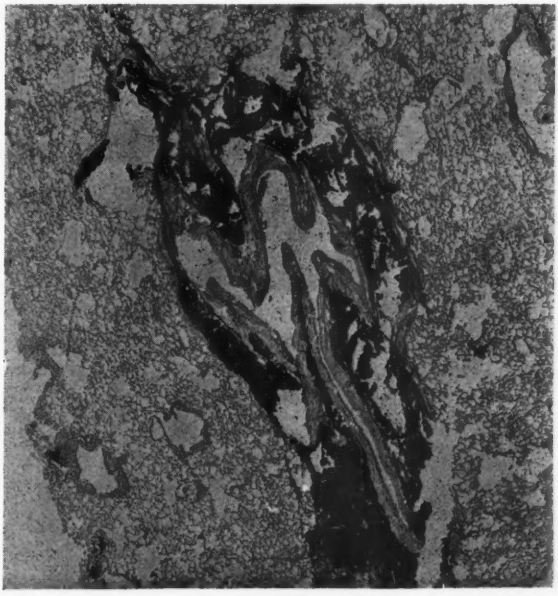


Fig. 5.—Perivascular space demonstration at vascular bifurcations.

DISCUSSION

By peripheral and central injection of a radiopaque solution under pressure into the cleavage plane between the pulmonary vessel walls and the surrounding tissues at the hilum of the dog's lung in the living animal, as well as in individual lung specimens and in heart-lung preparations removed en masse, definite dissectable ipsilateral and corresponding contralateral perivascular spaces have been identified grossly, microscopically and roentgenographically.

The injected solution apparently follows the line of least resistance in spreading along this areolar cleavage plane. Embryologically, the pulmonary veins have as an adventitia a very loose mesenchymal structure whose elements are largely longitudinal and which may be very easily split under even slight injection pressure for a distance which, peripherally, is conjectural, and it has been suggested that the injected solution follows such a plane.[3] Within the lung, the bases of the marginal alveoli appear to make a tunnel-like investment for arteries and veins, enclosing the perivascular space between the vessel walls and the marginal alveolar bases. In the case of the arteries, it has been suggested that the injected solution is guided by the adventitial covering of the vessels peripherally and centrally.

With regard to the injection of the contralateral venous perivascular spaces, the possibility that the solution finds its way across the midline into the corresponding perivascular space by chance is to be considered. However, it is speculated that at the hilum this perivascular sheath represents an extension of the fibrous pericardium along the vessels. The pericardial space itself is apparently separated from the perivascular space by the reflection of the serous pericardium. The reflection of the pericardium at the junction of the pulmonary veins with the right atrium suggests a continuous nature for this space across the midline connecting the perivascular spaces of all the pulmonary veins as well as, probably, those of the superior and inferior vena cavae.[4]

From practical experience in the performance of pulmonary resections, exposure of the vessels at the hilum as well as in the fissures is greatly facilitated by dissecting within this areolar perivascular space, which is relatively avascular and has been found to remain surprisingly free even in cases exhibiting advanced lymphadenopathy, excepting, of course, those cases showing advanced calcification or carcinomatous infiltration.

Once this perivascular space is entered and the vessel freed within its tunnel, clean incision of any overlying structures can be practiced with safety. This will often save much in time as well as offer freedom from annoying bleeding.

SUMMARY

The existence of a readily identifiable perivascular space about the pulmonary vessels has been anatomically demonstrated by gross, microscopic and

roentgenographic methods, showing the relations of this space to the vascular trunks and arborizations within the lung. Its relation to the pericardium and the contralateral vascular bed has been commented upon.

The information acquired concerning the nature and extent of these perivascular spaces is of great practical value in performing pulmonary resections in clinical cases, and may well explain pathologic processes in several clinical conditions.

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CYSTIC DISEASE OF THE LUNGS

FRANCIS N. COOKE, M.D.,* MIAMI, FLA., AND BRIAN BLADES, M.D.,
WASHINGTON, D. C.

THE incidence of cystic disease of the lungs is greater than earlier reports would appear to indicate. Although pulmonary cysts have long been recognized as a pathologic entity, the diagnosis was infrequently made until Koontz[1] introduced the subject into American literature in 1925. Eleven years later Schenck[2] was able to find only 233 cases in the literature, two-thirds of which were in foreign publications. Since that time the importance of this disease has become well recognized, as is evidenced by the now voluminous literature on the subject. The incidence, however, has been difficult to ascertain, principally because of differences in classification and variations in nomenclature. Hospital dispositions and routine autopsy reports are recognized sources of information on disease incidence. At Walter Reed Army Hospital there were 51,199 dispositions during the period from February, 1947, to January, 1951. Of this group there were twenty-one patients in whom the diagnosis of congenital bronchogenic cysts was made. The incidence based on these data is forty-two cases of bronchogenic cysts per 100,000 hospital dispositions. Other pulmonary cysts such as subpleural blebs and bullous emphysema could not be traced because of improper classification. However, during this period there were fourteen cases of recurrent pneumothorax that were caused by rupture of subpleural blebs treated surgically.[3] Weaver and von Hamm[4] reported two cases of pulmonary cysts in 6,000 consecutive autopsies, although Lederer[5] found none in 5,000 autopsies, many of which were performed on infants and children. The advent of routine chest roentgenograms has been another source of information in the establishment of the incidence of this disease. Edwards and Ehrlich[6] found two cases of pulmonary cysts and one case of bullous emphysema in preinduction chest roentgenograms of 41,819 inductees and guardsmen. From their figures it can be estimated that the incidence of congenital cystic disease of the lungs in asymptomatic young adults is five per 100,000 population.

It is obvious from the differences in the above figures that neither routine roentgenograms, autopsy specimens, nor hospital dispositions alone give an accurate picture of the incidence of cystic disease of the lungs. This is particularly true of x-ray examinations when it is realized that routine chest roentgenograms will not reveal all types of pulmonary cysts. Two of the cases reported in this series could not have been diagnosed by routine chest roentgenograms.

It is even more difficult to determine the incidence of pulmonary blebs and bullae; this is due in a large measure to the lack of uniformity in diagnosis and in most instances the lack of pathologic specimens to confirm the clinical impression. However, it can be stated with some conviction that cystic disease of

From the Surgical Service, Walter Reed Army Hospital.
Received for publication Nov. 17, 1951.
*Formerly Assistant Chief, Surgical Service, Walter Reed Army Hospital.

the lungs is a relatively common disease and that the diagnosis must be considered in any case in which chest symptoms persist and in which the diagnosis is in doubt.

There have been so many articles in the recent medical literature on cystic disease of the lungs that the authors hesitate to add more to what is already an overcrowded field. Despite the extensive literature on this subject, there is still much confusion as to the classification and nomenclature of this disease. Mooreman,[7] in the chapter on pulmonary cysts in *The Chest and the Heart,* makes this statement: "Increasing knowledge has not only failed to simplify diagnosis but it has confused rather than clarified the question of classification." This state of confusion is shared by other authors. In the 1947 edition of Boyd's[8] *Surgical Pathology,* this statement is made: "It is not possible to write a satisfactory account of cysts of the lung for the pathology is so confused and there is no correlation between the pathological and clinical picture." The varied nomenclature has indeed served to becloud the issues. At the Armed Forces Institute of Pathology[9] in Washington, D. C., there are twenty-eight synonyms under which cases of cystic disease of the lung are filed (Table I).

TABLE I

Congenital bronchiectasis	18
Fetal bronchiectasis	1
Embryonic cyst of the lung	1
Cyst, multiple, lung, congenital	3
Cystic bronchiectasis	12
Polycystic disease, congenital	2
Multiple pulmonary cysts	15
Bronchogenic cysts	99
Emphysema, congenital	1
Adenoma, bronchogenic, congenital	1
Cyst, bronchial, congenital	6
Cyst, solitary, congenital, pulmonary	60
Bronchiectasis, bronchiolar	1
Cysts, inclusion, multiple, lung	1
Cystlike cavity, lung	1

TABLE II

Bronchiectasis neonatorum
Atelectatic bronchiectasis
Telangiectasis
Bronchiolectasis
Cystic fetal bronchial adenoma
Honeycomb lung
Congenital pulmonary lymphangiectasis
Congenital cystic malformation of the lung
Cystic inclusion of the lung

Other synonyms have been gleaned from the literature (Table II). Many of the diagnoses listed here were used by earlier writers and were based on the then current concepts of the etiology of the disease. Koontz,[1] and later Schenck,[2] in a clinicopathologic study of cystic disease of the lung, reported in detail the various theories of pathogenesis which have at one time or another been proposed for congenital cysts of the lung. Many of these older terms have been discarded and the theories of pathogenesis discredited. However, there are still a host

TABLE III. CYSTIC DISEASE OF THE LUNG

I. Congenital Pulmonary Cysts.
A. Bronchogenic cell type
1. Solitary
2. Multiple
B. Alveolar cell type
1. Solitary (balloon cyst, pneumatocele)
2. Multiple
C. Bronchogenic and alveolar types combined
II. Acquired Pulmonary Cysts.
A. Bullous emphysema
B. Subpleural blebs

of pathologic conditions erroneously classified under cystic disease of the lung, and there are also many cases of cystic lung disease which are not recognized and therefore improperly classified. In recent years we have used a classification which includes all types of cystic lung disease, and which we believe will be acceptable to both clinician and pathologist. It is not the purpose of the authors to add to the nomenclature already exhaustive in variety and scope. On the contrary, this classification utilizes the terminology which is most frequently found in present-day literature (Table III).

For the purpose of classification, cystic disease of the lungs can be divided into two large groups: the congenital and the acquired.[10-12] The acquired type of so-called cystic lung disease should probably be included under emphysema and not in this classification. However, because most authors include acquired as well as congenital cysts in their series, and also because it is occasionally not possible to distinguish between the two, both types of cystic disease will be discussed as a group.

Chronic lung abscess has not been included in this classification. Although such cavitations are sometimes termed acquired cysts or abscess cysts, the justification for such terminology being that in some chronic pulmonary abscesses, there is an ingrowth into the cavity of cuboidal or columnar epithelium.[13] Although it is a well-recognized fact that squamous metaplasia frequently occurs in such cases, ciliated epithelial replacement of the pyogenic membrane of an abscessed cavity occurs so rarely, if it occurs at all, that the authors have purposely not included that type of case. The term chronic lung abscess defines so clearly that pathologic entity that an attempt to include it in a classification of pulmonary cysts would in our opinion be a mistake.

CONGENITAL PULMONARY CYSTS

Congenital cysts of the lung are one of three types, depending upon the cellular component of the cyst wall. The bronchogenic cysts are those in which the wall of the cyst is lined by bronchial mucosa with either tall columnar or cuboidal ciliated cells. These cysts may be single or multiple. They may be confined to a segment or diffusely scattered throughout the entire lung. Small, diffusely scattered cysts which communicate with the bronchi have the appearance on bronchography of saccular bronchiectasis. When seen in infancy or childhood, this type case has frequently been classified as congenital bronchiectasis, fetal bronchiectasis, or bronchiectasis neonatorum. Superimposed infec-

tion will in many instances make a proper diagnosis difficult, particularly if the infection is long standing. There are certain features in which the congenital malformation differs from acquired bronchiectasis. The distribution of the lesion is an important indication of the nature of the disease. In acquired bronchiectasis the dependent portions of the lung, particularly the basilar segments of the lower lobes and lingular segment of the upper lobe, are most frequently involved. In congenital cystic disease of the small, diffuse type, the upper lobes are often the site of the lesion. In the congenitally malformed lung the cystic areas in many instances are of a uniform size compared to both tubular and saccular dilatations seen in acquired bronchiectasis. The histologic picture in the congenital malformation will characteristically show bronchial type mucosa unless superimposed infection has destroyed this membrane. In the acquired disease in which sacculations are apparent, there will be evidence of considerable inflammation and scarring. Two cases of congenital cystic disease of the lung have recently been reported by Ravitch and Hardy[14] in which they described the bronchographic appearance of the cysts as "grapes hanging from a stem."

As pointed out by Anspach and Wolman,[15] the postnatal behavior of congenital cysts will depend in a large degree upon whether or not they communicate with a bronchus. Although a bronchial communication may not be present, infection may enter the cyst by extension from adjacent diseased tissue. In the authors' experience all infected cysts have communicated with the airway; whether the infection preceded the bronchial communication or not is not known. The converse that all cysts with bronchial communications are infected is, of course, not true.

The large solitary cysts of bronchogenic origin are frequently found projecting from the mediastinum. Some of these cysts have on occasion been classified as accessory lobes or accessory lungs.[16] DeBakey[17] considers the appearance of normally developed lung parenchyma about the periphery of the bronchogenic cyst sufficient reason to classify these malformations as accessory lobes despite the fact that the vascular pedicle arises from the systemic rather than the pulmonary circulation. In the classification proposed here mediastinal cysts of bronchogenic origin have purposely not been included.

The alveolar type cysts are those in which the wall of the cyst is composed of flat squamous cells characteristic of the air sacs.[18] This type of cyst always has a bronchial communication. Rarely, as a result of infection, these cysts may contain both fluid and air. The majority, however, are air cysts and produce symptoms by encroaching on normal lung tissue. Spontaneous cures have occurred,[2, 19, 20, 21] and such a case will be reported in this paper. Spontaneous cures may occur as a result of closure of the bronchial communications and resorption of the air with obliteration of the cyst. In the case of this type reported by Lloyd,[19] the period of follow-up covers ten years. Although the cyst he described occurred in a small child and appeared to be a solitary cyst, it was classified as a case of bullous emphysema.

Benjamin and Childe[22] reported a series of nineteen cases of "Localized Bullous Emphysema Associated with Pneumonia" in children from ages 3

months to 13 years. In a similar article entitled "Regional Obstructive Emphysema in Infants and Children," Coffey[23] reported on twenty such cases. All of the patients in both series underwent spontaneous cure. The cases illustrated in those articles are similar to the type cases which we have classified as congenital in origin. Although we are not convinced that such a stand on our part is entirely correct, there are certain facts which must be considered. Pneumonic infiltration is a relatively frequent complication of cystic lung disease, and it is possible in some of their illustrated cases that the pulmonary cysts were complicated by pneumonia rather than cystic areas resulting from the pneumonia. In addition, bullous emphysema as we know it in the adult runs a clinical course so entirely different from the cases reported by Benjamin and Childe and by Coffey that one hesitates to accept the two pathologic conditions as similar. If in the course of future investigation it is demonstrated that this disease is bullous or obstructive emphysema, then it will be necessary to divide bullous emphysema into an adult and an infant type because of the extreme difference in the clinical course of the two disease processes. At the present time we are manifestly handicapped because there have not been specimens for pathologic examination.

The large solitary balloon cysts or pneumatoceles have been included under congenital cysts for several reasons. These cysts occur more frequently in infants and children.[3, 12, 24] The structure of the solitary cysts is quite different from the emphysematous bullae[25] from which they must be differentiated. The solitary cyst is completely lined with alveolar type cells and as a rule has a single bronchial communication. All adjacent pulmonary segments are anatomically normal except for compression atelectasis due to the enlarging balloon cyst. The fact that these cysts have been found in adults does not necessarily refute the claim that they are congenital in origin. The important point is not whether these cysts are congenital in origin or not, but because of the difference in prognosis and management, they must be distinguished from emphysematous bullae.

The congenital cysts in which there exist both bronchogenic mucosa and the flat alveolar cells of the air sacs are rare, but have been reported.

Congenital cystic disease of the lung results from an anomalous development of the lung anlage, and the characteristic cellular components of the malformation will be determined by the age of the individual at the time that the malformation occurs. If Broman's[26] observations are correct, the malformations could conceivably occur after birth and may account for some of the bizarre clinical manifestations seen in infants and children. He quotes the work of von Selenka, Narath, and Brehmer to corroborate his observations. Broman states ". . . that the definitive lung parenchyma (total alveolar mass of the adult) of man and the other placentalia, for the most part becomes built after birth." He further states that ". . . entirely new alveoli and alveoli processes develop after birth." This process is complete and adult type lung parenchyma is established in early adolescence.

The following case reports will be used to illustrate the proposed classifications. The authors are indebted to Colonel Joe M. Blumberg, M.C., Pathologist,

Walter Reed Army Hospital, and Dr. Theodore Winship, Consultant in Pathology, Walter Reed Army Hospital for reviewing with us the pathology in each case. Some of the problems which arise in the management of cystic lung disease will be discussed.

Fig. 1.—(Case 1.) Posteroanterior roentgenogram of the chest showing multiple radiolucent areas in the left lower lung field.

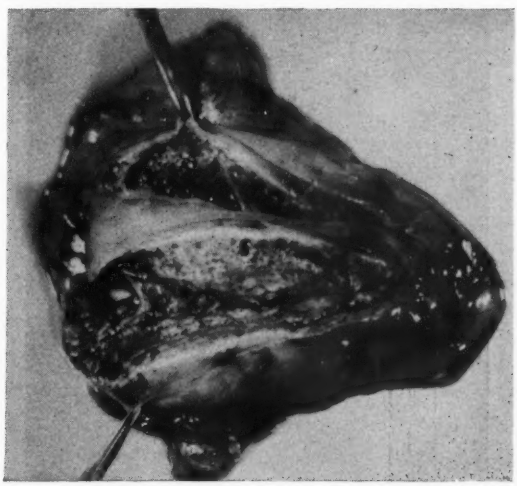

Fig. 2.—(Case 1.) Specimen showing infected bronchogenic type cysts.

CASE 1.—A 23-year-old white man was admitted to the hospital with chest pain, productive cough, and fever of six weeks' duration. During the nine months prior to admission, the patient had had several similar episodes. Each episode which was diagnosed as pneumonia had responded slowly to antibiotics. A chest roentgenogram showed multiple radiolucent areas in the left lower lung field (Fig. 1), in one of which there is a fluid level. Bronchograms showed no filling of the superior segment of the left lower lobe and one large saccule in the posterior basilar segment. A diagnosis of cystic disease

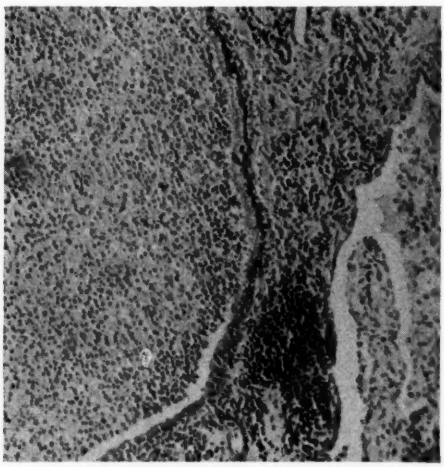

Fig. 3.—(Case 1.) Photomicrograph showing the ciliated columnar epithelium. Neutrophilic granulocytes can be seen in the exudate.

Fig. 4.—(Case 2.) Posteroanterior roentgenogram of the chest showing multiple radiolucent areas in the left upper lobe.

of the lung confined to the left lower lobe was made and a left lower lobe lobectomy was performed. The specimen revealed many cystic areas in the superior and posterior basilar segments of the left lower lobe which were filled with pus and showed evidence of considerable inflammatory reaction involving the contiguous lung tissue (Fig. 2). The cyst wall on the microphotograph shows the tall, columnar ciliated bronchial epithelium (Fig. 3). Neutrophilic granulocytes are seen in the exudate. This case is classified as congenital cystic disease of the lung, bronchogenic type, multiple cysts confined to the left lower lobe.

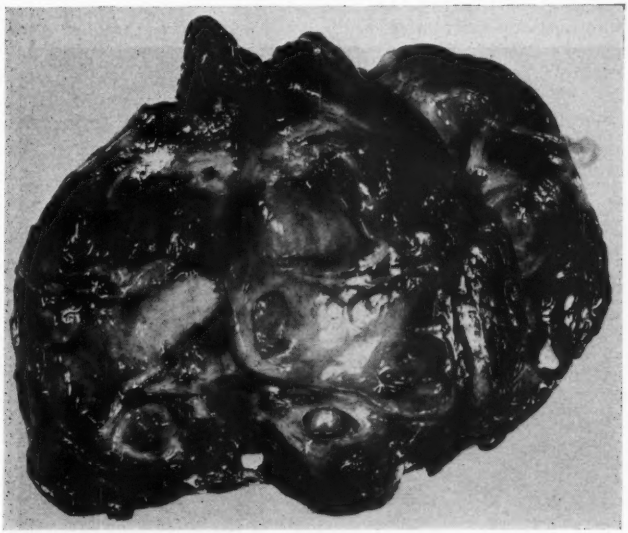

Fig. 5.—(Case 2.) The specimen showing large multiple cysts involving the apical posterior segment of the left upper lobe.

Fig. 6.—(Case 2.) Photomicrograph of the cyst wall showing tall columnar, ciliated epithelium.

CASE 2.—This 31-year-old white man was admitted with the following history: six months prior to admission he complained of pain in the chest, became febrile, and coughed up large amounts of pus. A roentgenogram at that time revealed radiolucent areas in the left upper lobe (Fig. 4). Later roentgenograms of the chest revealed decrease in the inflammatory reaction in the left apex, but the radiolucent areas were still apparent. The patient became asymptomatic. Bronchograms revealed a normal tracheobronchial tree on the left except for absence of filling of the apical posterior segment of the upper lobe.

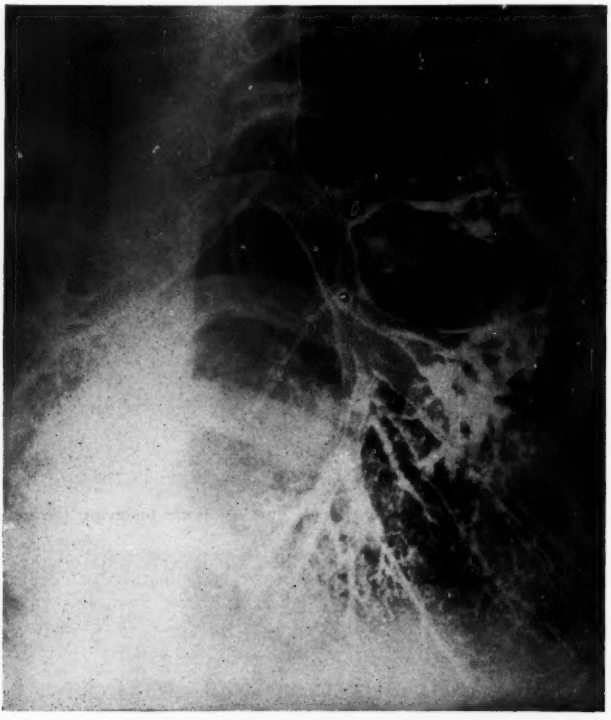

Fig. 7.—(Case 3.) Bronchography showing what was believed to be saccular bronchiectasis involving the right upper and right middle lobes.

Tuberculosis work-up was entirely negative. At operation cystic disease confined to the apical posterior segment was removed by segmental resection. The patient made an uneventful convalescence and returned to duty.

Pathology: Numerous fairly large cysts were demonstrated (Fig. 5). Tall, columnar ciliated epithelium lined the cyst walls (Fig. 6). This case is also classified as congenital cystic disease of the lung, bronchogenic type, multiple cysts, confined to the apical posterior segment of the left upper lobe.

Comment.—These two cases represent fairly large bronchogenic cysts which were found deep in the structure of the lung. The symptoms were caused by secondary infection. The cysts communicated at least periodically with the

airway which allowed for drainage of their contents. Repeated respiratory infections with productive cough and fever and persistence of abnormal roentgenograms of the chest brought these patients to the hospital.

CASE 3.—This 18-year-old white man gave the history of an episode of chest pain and hemoptysis at the age of 14 years following a tonsillectomy. At that time he was told that he had a lung abscess which drained beneath the right axilla. This drained periodically for two years. Prior to enlistment he had been asymptomatic for two years. Soon after basic training, however, he had an upper respiratory infection following which he noticed purulent drainage and air escaping from the old sinus tract in his right axilla.

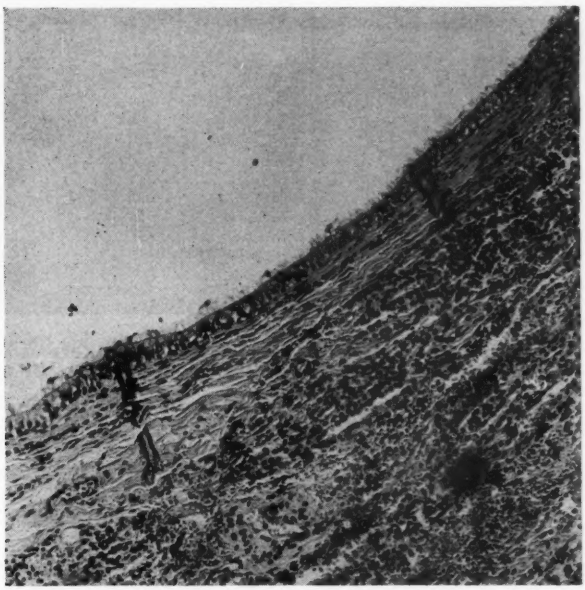

Fig. 8.—(Case 3.) Photomicrograph of a section taken through one of the cystic areas showing ciliated bronchogenic mucosa lining the cyst.

Bronchography revealed what was considered saccular bronchiectasis involving the right upper and right middle lobes (Fig. 7). The sinus tract communicated with a large bronchus in the right middle lobe. A right upper and middle lobectomy was completed. The operation was staged because of anesthetic difficulties. The patient made an uneventful recovery and was returned to military duty.

Pathologic examination showed small cystic areas which communicated with the small bronchi. These were diffuse throughout the entire upper and middle lobes. Microscopic examination of the tissue revealed the characteristic cellular pattern of congenital bronchogenic cysts (Fig. 8).

Comment.—The distribution of the cystic areas as seen on bronchograms, namely, that the disease was completely confined to the middle and upper lobes, plus the fact that the sacculations seemed fairly uniform in size with no tubular dilatations, suggested the possibility of congenital malformations within the

Fig. 9.

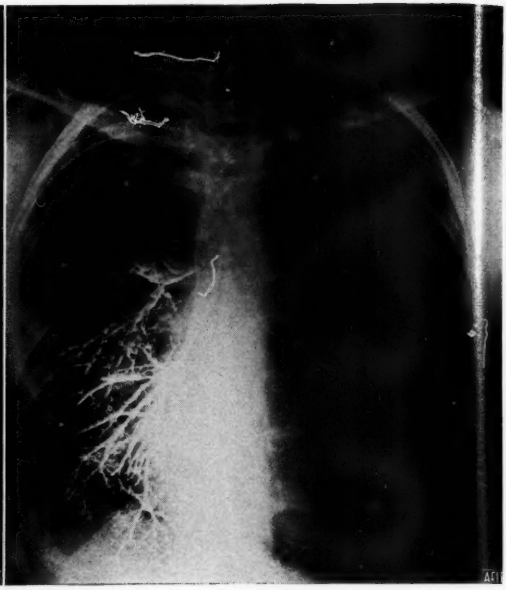

Fig. 10.

Fig. 9.—(Case 4.) Bronchography demonstrating saccular bronchiectatic dilatations involving the right lower and posterior segment of the right upper lobe.

Fig. 10.—(Case 4.) Postoperative bronchogram showing good expansion of the remaining pulmonary segments.

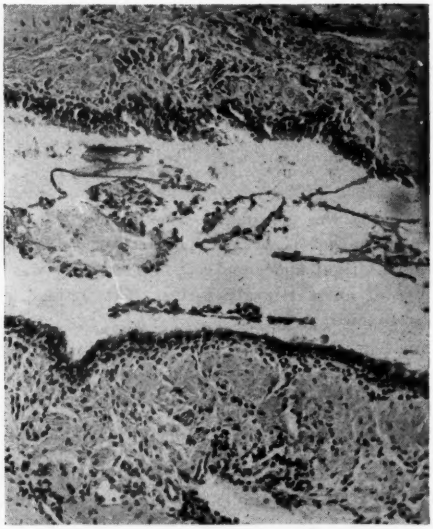

Fig. 11.—(Case 4.) Photomicrograph of a section through one of the cystic areas demonstrating bronchogenic type mucosa characteristic of congenital pulmonary cysts.

pulmonary parenchyma. Careful examination of the specimen by the pathologist confirmed the clinical diagnosis of congenital cystic disease of the lung, bronchogenic type, multiple, confined to the right upper and right middle lobes.

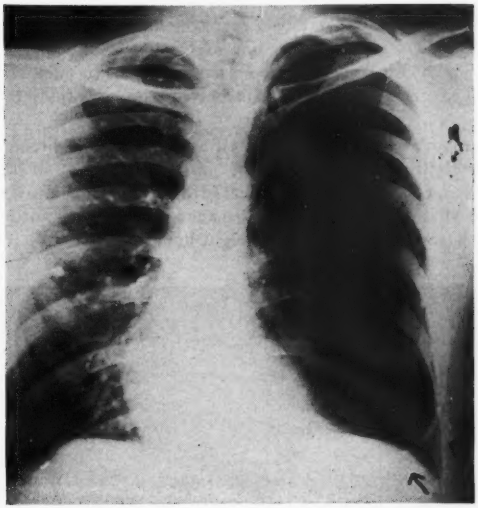

Fig. 12.—(Case 5.) Posteroanterior roentgenogram of the chest showing lack of lung markings and almost complete replacement of lung tissue of the left hemithorax. A small pneumothorax exists in the right lower lung field.

Fig. 13.—(Case 5.) Specimen at operation.

CASE 4.—This 21-year-old white man presented symptoms of a chronic productive cough of four years' duration. He gave a history of having had bronchopneumonia at four months of age with several recurrences of pneumonia during infancy. Bronchography revealed saccular bronchiectatic dilatations involving the entire right lower lobe and the posterior segment of the right upper lobe (Fig. 9). The patient was operated on, and a right lower lobectomy and segmental resection of the posterior segment of the right upper lobe was accomplished. The patient recovered and returned to duty. Postoperative roentgenogram of the chest revealed good expansion of the remaining pulmonary segments (Fig. 10).

The pathology report was of multiple small cysts lined with bronchial type epithelium involving the entire right lower lobe and the posterior segment of the right upper lobe (Fig. 11). These cystic cavitations communicated with the bronchi. This case is classified as congenital cystic disease of the lungs, bronchogenic type, multiple, confined to the right lower lobe and posterior segment of the right upper lobe.

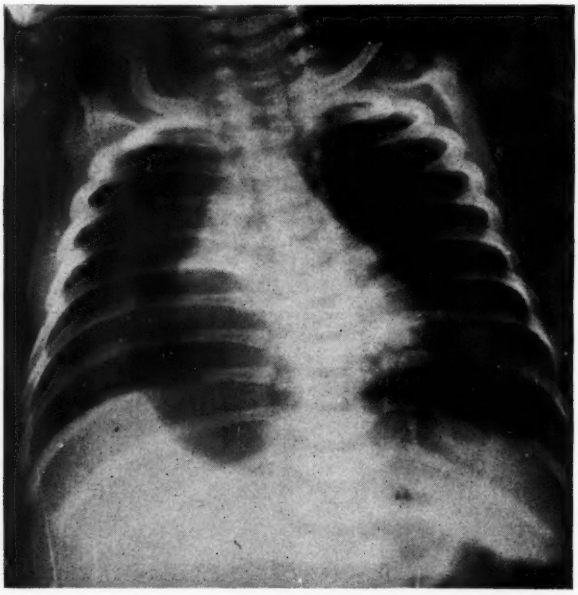

Fig. 14.—(Case 6.) Posteroanterior roentgenogram of the chest showing multiple cystic areas in both lung fields.

Comment.—This case represents congenital cystic disease of the lungs of the bronchogenic type which could easily have been confused with saccular bronchiectasis. The bronchographic findings of saccular dilatations of uniform size plus the diffuse distribution throughout the lower lobe and the posterior segment of the right upper lobe was the first clue that this was cystic disease and not acquired bronchiectasis. Pathologic examination which included a very careful inspection of the gross specimen showed the cystic areas to be lined with the characteristic columnar ciliated cells.

CASE 5.—This 27-year-old white man was admitted to the hospital with a diagnosis of pneumothorax. The patient was asymptomatic. Roentgenograms of the chest which

accompanied him showed complete lack of lung markings in the left hemithorax except for a few fine shadows about the pulmonary hilum. One film, however, which had been taken following thoracentesis showed air in the free pleural space and the wall of a cyst well outlined (Fig. 12). Operation was performed and a giant, solitary air cyst was removed (Fig. 13). The patient recovered and was sent to duty.

Pathologic examination: A large, solitary pulmonary cyst was seen, the walls of which were lined with flattened fusiform cells. This was classified as congenital cyst of the lung, solitary alveolar cell type.

Comment.—This type cyst represents a large, solitary, balloon cyst or pneumatocele which is most frequently found in infants and children. It is very thin walled and is often mistaken for a pneumothorax, as happened in this case. This cyst is classified as congenital. It should not be confused with emphysematous bullae.

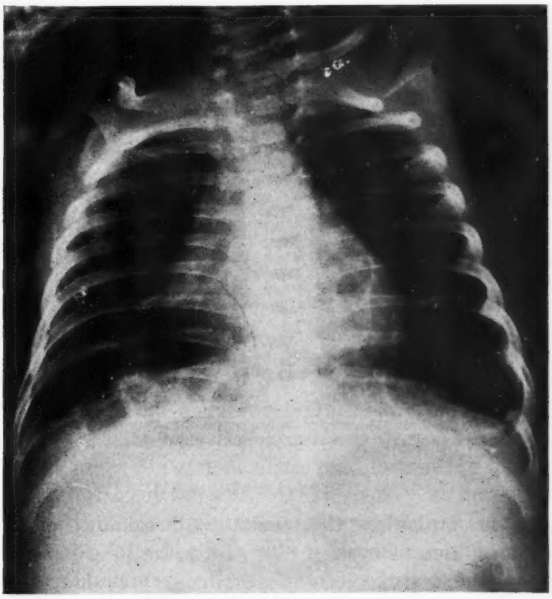

Fig. 15.—(Case 6.) Posteroanterior roentgenograms of the chest ten days later, showing increase in the number of cystic areas within the lung fields.

CASE 6.—This 5-week-old, normally delivered, Negro girl developed a severe respiratory infection with dyspnea and abdominal distention several days prior to admission. X-ray examination of the chest revealed several cystic areas in the lower lung fields, bilaterally (Fig. 14). The child improved symptomatically under treatment, but repeat x-ray examination showed enlargement of the cystic areas and an increase in the number of cysts until both lower lobes seemed to be diffusely involved (Fig. 15). The child improved with antibiotic therapy and within a week x-ray examination showed diminution in the size of the cysts. A diagnosis of congenital cystic disease of the lungs was made at that time. She was discharged from the hospital at the age of 7 weeks. During the following nine-month period she had several bouts of respiratory infections with cough and slight to moderate dyspnea. In each instance she improved remarkably with treat-

ment. The last several respiratory infections were notable in that dyspnea was absent. At the age of 10 months roentgenograms of the chest showed no evidence of disease (Fig. 16). Bronchograms adequately filled all pulmonary segments with no evidence of any cystic areas or bronchiectatic dilatations.

Comment.—This child has apparently undergone a spontaneous cure. Spontaneous cures of lung cysts have been reported.[19-23] Because of the age of the patient and the course of the disease, it is assumed that these cysts were congenital in origin. This case has been classified as congenital cystic disease of the lungs, alveolar cell type.

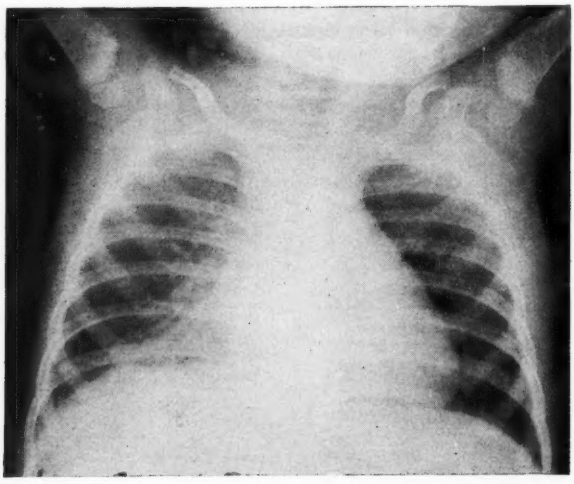

Fig. 16.—(Case 6.) Posteroanterior roentgenograms of the chest seven months following initial x-ray film showing a completely normal chest to this type of examination.

ACQUIRED CYSTIC DISEASE OF THE LUNGS

Emphysematous bullae are the result of a breakdown of the interalveolar septa with the formation of cystic areas within the lung parenchyma. As this process continues the cystlike space is limited at the lung periphery by the visceral pleura. If the visceral pleura be opened over a bulla, the air space beneath will not be lined by squamous cells as is found in a balloon cyst of the congenital type, but a disintegrating lung parenchyma will be seen to make up the walls and base of the bulla. Fine blood vesse'ls completely stripped of supporting lung parenchyma can be seen to cross the air sac. Strands of connective tissue and fine bronchioles also denuded criss-cross the bulla. Multiple small communications with the adjacent bronchi are apparent. Bullae are almost always multiple, but they may be confined to a segment or a lobe. The upper lobes in our experience have been most frequently involved.

Subpleural blebs are the result of rupture of the elastic fibers which bind the pleura to the underlying lung parenchyma.[27] They characteristically occur at the apices of the lung. Small blebs may coalesce to form larger ones, or they

may be multiple and discrete and be scattered diffusely over the upper surface of the lung. According to Miller,[27] all cases of subpleural blebs are associated with well-established pulmonary emphysema. Miller also pointed out the similarity between the bleb and the bulla and suggested that the manner of formation is the same. Is it possible that the seemingly innocuous bleb is the precursor of the emphysematous bulla?

Rupture of subpleural blebs is the most frequent cause of spontaneous pneumothorax and is the most common cause for these patients to seek medical attention.[28, 29] In some instances chronic pneumothorax and fibrothorax have resulted from rupture of subpleural blebs and have necessitated decortication to restore pulmonary function.

The ball valve mechanism has been given considerable credit for the progressive enlargement of blebs, bullae, and balloon cysts. Hayashi[30] was able to find microscopic evidence of the valve mechanism which presumably explained the progressive enlargement of air cysts. It is true that a tension cyst or an emphysematous bulla enlarges at the expense of normal lung parenchyma, and the end result is the same as if a perfectly functioning valve were present at the site of the bronchial communication. However, the aerodynamics involved in enlarging bullae and cysts can perhaps be explained in another way. A cyst enlarges because the intracystic pressure builds up to such a degree that the adjacent pulmonary tissue unsupported by a pressure equal to that within the cyst gives way before the enlarging air sac. Intracystic pressure of sufficient force to cause enlargement can result from coughing or straining. Just prior to expulsion of air as in coughing, the glottis is closed and considerable endobronchial pressure is built up by the action of the accessory muscles of respiration. At this time the pressures are equalized throughout all the lung structures that are in communication with an airway, i.e., cyst, bulla, or bleb. When the glottis is opened the endobronchial pressure immediately falls to near zero;[31] however, the relatively small bronchial openings which communicate with the cysts do not allow for an immediate readjustment of the pressure within the cysts and the thin, flaccid walls of the cyst expand at the expense of the adjacent pulmonary tissue. As this process is repeated, the cystic areas enlarge. The thick walls of the bronchogenic type cysts do not allow such ease of expansion. For this reason tension cysts are as a rule not of the bronchogenic type although such a case was recently reported by Allbritten.[12]

Head and Avery[32] described the actions of bullae into which a thoracoscope had been passed. During respiration the bullae could be seen to behave in a paradoxical manner. At the beginning of inspiration the cavity was filled with air whereas expiration caused the cyst walls to bulge inward. These observations would seem to be in conflict with our statements, but it must be pointed out that their observations were made during quiet respiration. Although the effect of a ball valve is present, we have not been able to demonstrate in our series a competent valve mechanism between cyst and bronchus. At operation manual compression of the cyst has in every instance demonstrated the ease with which this type cyst could be collapsed. If our observations are correct it seems improbable that enough pressure can be built up within a cyst by quiet respira-

tion to destroy adjacent lung tissue. To express the problem in another manner, the pressure gradient between the air in the cyst and that in the normally functioning pulmonary tissue must be such that sufficient force is exerted against the cyst wall to cause rupture of the alveolar septa and even the interlobular

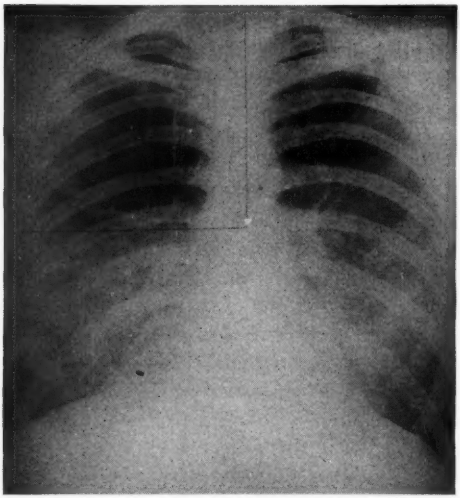

Fig. 17.—(Case 7.) Posteroanterior roentgenogram of the chest. Inset shows lacy marking in the right upper lung field characteristic of bullous emphysema.

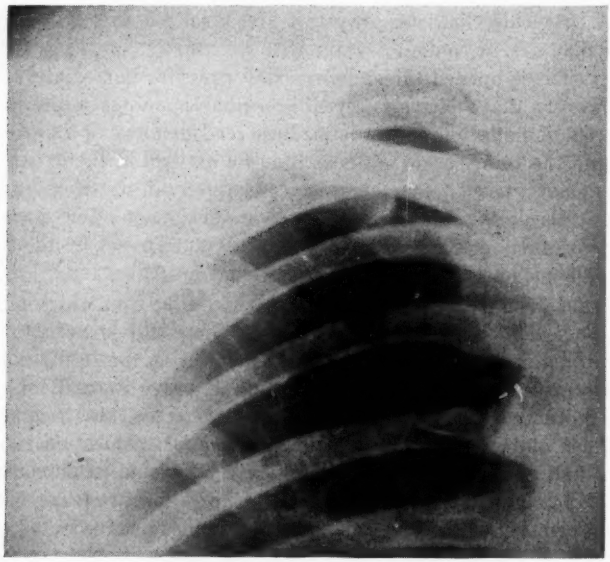

Fig. 18.—(Case 7.) A close-up picture of the inset.

septa. Such pressure can easily be built up in the pulmonary system by coughing, but at the time the glottis is closed the pressure is equal throughout the entire thoracic cavity and it is only upon sudden release of this pressure by opening the glottis that the pressure gradient between the air within the cyst and the air in the normal lung parenchyma becomes sufficient to allow expansion of the cyst.

The origin of pulmonary bullae has been thought to be due to inflammation and partial occlusion of the smaller air passages. This must undoubtedly play a large part. In all of the cases of bullous emphysema in our series a severe, chronic cough has been present.

The surgical treatment of selected cases of pulmonary blebs and emphysematous bullae has in recent years become well established.[3, 12, 32-36] The following cases are representative of the group that have been treated surgically. The results of this treatment have been uniformly good and all patients have been returned to military duty with one exception; the case history of that patient is reported below.

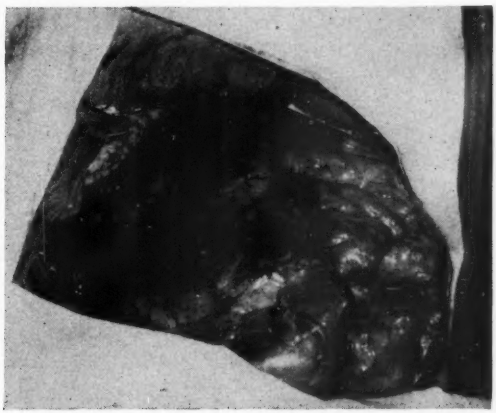

Fig. 19.—(Case 7.) The right upper lobe at operation has almost been completely replaced with large emphysematous bullae.

CASE 7.—A 34-year-old white man complained of a cough which was productive in the morning of a small amount of sputum and slight dyspnea on exertion. In the morning his cough was so severe that he frequently vomited. The exertional dyspnea was particularly noticeable because the patient had been an instructor in a Ranger Battalion during the war and at which time he had undergone rigorous training with no apparent difficulty. He volunteered the information that in recent years he smoked three packages of cigarettes per day. Chest roentgenograms revealed emphysema, bullous type, involving both upper lobes, more marked on the right (Figs. 17 and 18). Right thoracotomy was performed, and the right upper lobe was found to be almost completely replaced by emphysematous bullae (Fig. 19). The right middle and right lower lobes were free of disease. The multiple cysts had enlarged to such a degree after the pleural adhesions were lysed that the pulmonary hilum could not be adequately exposed until the cysts were collapsed by manual compression and clamps placed across the base of the cysts. The bullae

were easily compressed, and no valve mechanism was apparent. Lobectomy was completed without incident.

Forty-eight hours postoperatively the patient developed atelectasis on the right which necessitated aspiration bronchoscopy. Despite repeated aspiration of the airway, his mediastinum failed to shift back to its normal position. The heart was markedly displaced, and the patient developed paroxysmal auricular tachycardia. Frequent bronchoscopic aspirations of the right main-stem bronchus failed to relieve the marked mediastinal shift. It was assumed that the bullae in the left apex had become overdistended at the time of the onset of atelectasis and that, despite all efforts to reduce the size of these bullae, they continued to impinge on normal lung and mediastinal structures to such a degree that the existence of the patient was threatened. In a desperate effort to reduce the bullae in the left apex, a trochar was placed through the left anterior chest and a catheter was placed in the largest presenting bulla. Suction was applied (Fig. 20).

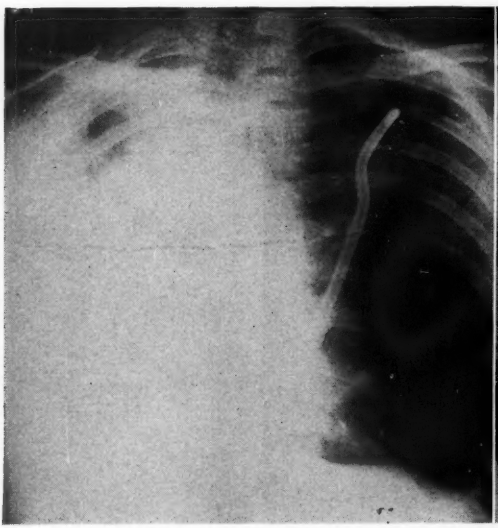

Fig. 20.

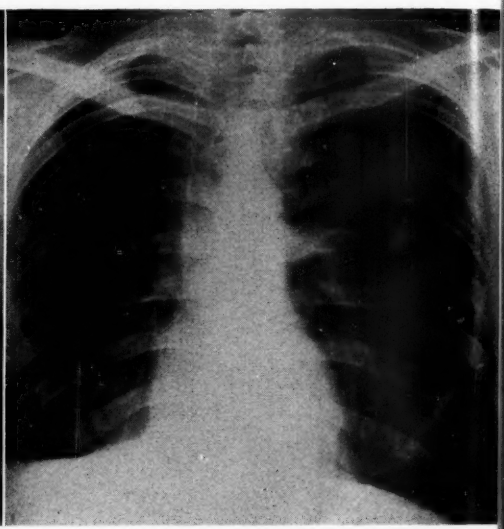

Fig. 21.

Fig. 20.—(Case 7.) Portable roentgenogram of the chest showing intercostal catheter into a large bulla in the left apex. The marked mediastinal shift is evidenced.

Fig. 21.—(Case 7.) Postoperative posteroanterior roentgenogram of the chest showing good expansion of the remaining pulmonary segments. At this time the patient regained vital capacity of 4.5 liters.

This failed to relieve the situation, and on the fifth postoperative day, three days after the onset of these most distressing complications, a thoracotomy was performed on the left and numerous large bullae involving the anterior and apical posterior segments of the left upper lobe were found. There was no involvement of the lower lobe. As soon as the chest was opened, the patient under endotracheal anesthesia improved considerably. The bullae were resected. Despite the occurrence of pneumothorax on the left side which required that suction be applied to the thoracotomy tubes, in order that adequate ventilation of the lungs could take place, the patient recovered.

Pathologic diagnosis: Bullous emphysema, bilateral, confined to the upper lobes.

Comment.—This patient represents a case of bullous emphysema localized to the upper lobes of both lungs. It is interesting to note that he apparently

was free of disease five years prior to his admission to the hospital, at which time he had demonstrated repeatedly his ability to do the most strenuous type of physical exertion. At that time it must be presumed that he had no pulmonary disease. It is also interesting to speculate as to what role violent cough-

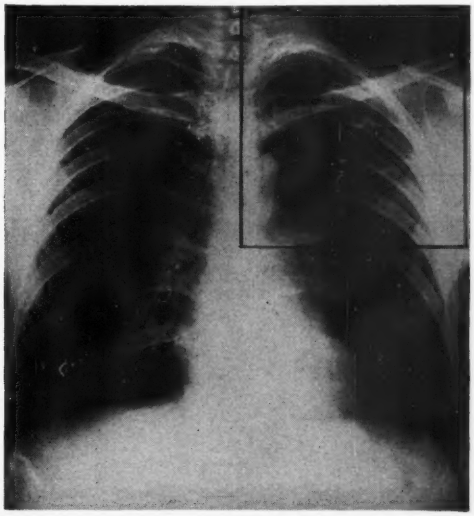

Fig. 22.—(Case 8.) Posteroanterior roentgenogram of the chest. Inset shows characteristic appearance of bullous emphysema.

Fig. 23.—(Case 8.) Close-up of inset.

ing played in the production of the tremendous emphysematous bullae found at operation. The rather serious complications which arose as a result of his having bilateral bullae necessitated a thoracotomy on the left five days after a right upper lobectomy. Such a complication reported by Dugan and Samson[28] caused a fatality in their series. They suggested that perhaps a catheter placed into the expanding bulla would relieve the tension and prevent the compression of vital structures. This was tried in our patient and failed, probably due to the large number of bullae which were present and as one collapsed others expanded to fill the space provided. Although this patient did not return to duty because of the uncertain prognosis of his disease, he did regain a vital capacity of 4.5 liters and is living a useful and active life (Fig. 21).

Fig. 24.—(Case 8.) At operation large emphysematous bullae replaced the apical posterior segment.

CASE 8.—This 39-year-old white man had a chronic, slightly productive cough for ten years which he attributed to smoking cigarettes. Routine x-ray examination had revealed emphysema localized to the left upper lobe (Figs. 22 and 23). Increase in the size of the bullae was noticed when the films were compared to roentgenograms taken on previous admission. Bronchography outlined a normal tracheobronchial tree. Because of the localized nature of the lesion, exploratory thoracotomy was thought to be indicated. At operation, large emphysematous bullae had almost completely replaced the apical posterior segment of the left upper lobe (Fig. 24). There was no other evidence of disease in the chest. The bullae were resected. The patient was returned to duty.

Pathologic diagnosis: Emphysema, bullous type, with alveolar bleb formation.

Comment.—This case represents the type of bullous emphysema which is localized to a segment and which lends itself well to surgical removal. This is classified, of course, as acquired type of pulmonary cysts.

The following two cases were classified as emphysematous blebs:

CASE 9.—A 28-year-old white soldier was admitted to the hospital after his third episode of spontaneous pneumothorax. He had had repeated surveys for tuberculosis, all of which had been negative. There was no evidence of disease other than the pneumothorax which was the transfer diagnosis. On examination of the roentgenograms, a small bleb could be seen at the left apex (Fig. 25). A thoracotomy was performed, the bleb was excised, and the surface of the upper lobe was powdered with sterile talc. The patient made an uneventful recovery and was returned to duty.

Fig. 25.—(Case 9.) Posteroanterior roentgenogram of the chest showing pneumothorax on the left and at the apex an emphysematous bleb.

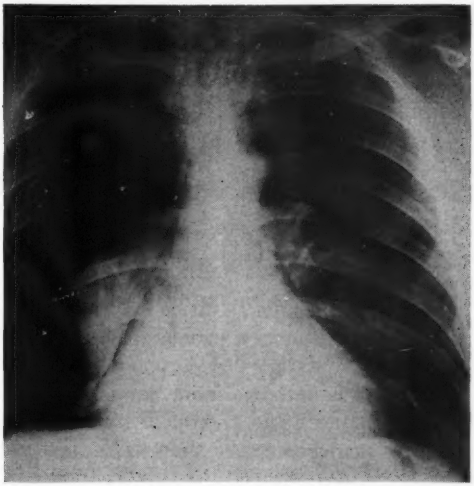

Fig. 26.—(Case 10.) Posteroanterior roentgenogram of the chest reveals pneumothorax on the right, and very faintly seen a large emphysematous bleb.

CASE 10.—A 29-year-old white man was admitted to the hospital following a spontaneous pneumothorax (Fig. 26). On chest x-ray examination, a large bleb could be seen at the uppermost portion of the collapsed right lung. Tuberculosis survey was negative. There was no evidence of disease. At operation a large subpleural bleb (Fig. 27) was excised, and the surface of the upper lobe was poudraged. The patient made an uneventful convalescence and was discharged to duty.

Comment.—The two preceding cases are representative of the type of subpleural blebs which are the most frequent cause of spontaneous pneumothorax. It has been our policy when confronted with the problem of spontaneous pneumothorax in otherwise healthy individuals to treat the pneumothorax conservatively. Many of these cases, of course, have not had recurrence. However, in patients who have recurrent spontaneous pneumothorax on three or more occasions and in those in which the subpleural blebs can be visualized, we have elected to do a thoracotomy with excision of the bleb or blebs and poudrage of the lung surface. The poudrage serves the purpose of causing the parietal and visceral pleura to become adherent in that region and also tends, because of the inflammatory reaction, to cause a thickening of the visceral pleura and lessen the tendency of rupture of a bleb. The patients treated in this manner have all been returned to military duty.

Fig. 27.—(Case 10.) At operation the large solitary bleb is demonstrated.

SUMMARY

The incidence of cystic lung disease is much greater than is indicated by figures based on routine roentgenogram or necropsy examinations. A classification of the various types of cysts has been proposed. A standardization of the nomenclature would facilitate statistical analyses and help clarify much of the confusion in regard to prognosis and treatment. Some of the many problems occurring in the surgical management of these cases have been discussed.

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THE FATE OF AN ISOLATED SEGMENT OF THE ESOPHAGUS

W. RALPH DEATON, JR., M.D.,* AND H. H. BRADSHAW, M.D.
WINSTON-SALEM, N. C.

RESECTION of the esophagus is very difficult when there is marked fixation of the esophagus to the adjacent tissue. Such fixation is especially severe in cases of caustic stricture, and in carcinoma if the growth has spread beyond the esophageal wall. The advisability of leaving the involved segment of the esophagus in place in such cases and construction of a side-tracking anastomosis, either esophagoesophageal or esophagogastric, was considered, and an experiment set up to evaluate this procedure in dogs.

METHOD

Nine mongrel dogs were used. In order to provoke adhesions to the segment of esophagus that was to be isolated, and so to simulate actual conditions, right thoracotomy was performed, and a 5 cm. segment of the lower thoracic esophagus wrapped with a single layer of cellophane which had been previously tested for tissue irritability (active agent dicetyl phosphate). Approximately four weeks later, when esophagoscopy demonstrated a narrowing of the lumen of the esophagus at the site of the wrapping, left thoracotomy was performed. In each animal there were dense adhesions to the esophagus at the level of the cellophane wrapping. The esophagus was divided 1 cm. above and 1 cm. below the involved area, and an anastomosis was constructed between the proximal esophagus and the distal esophagus or stomach (in three cases the stricture was so low as to necessitate the use of the cardia for the anastomosis). In every case the diaphram was opened and a sufficient amount of stomach brought into the chest to allow the anastomosis to be constructed without undue tension. In Group I dogs the isolated segment of the esophagus was closed at each end with continuous silk sutures. In Group II dogs each end of the isolated segment was left open. In Group III dogs the segment was split lengthwise so as to leave an "opened tube" of esophagus. The bleeding vessels at the cut edges were clamped and tied. The operations were performed with aseptic technique. Each dog received subcutaneous fluids the day of operation, water and milk for the first to the seventh postoperative day, and regular dried kennel rations thereafter.

RESULTS

At varying intervals (Table I) after the second operation the dogs were sacrificed for further study. In every case, save that of dog 253 of Group III, the isolated segment of the esophagus had closed off to become a mucus-filled cyst (Fig. 1). The cysts varied in size from 3 to 6 cm. in diameter (Table I), with an average size of 4.5 cm. The material in the cyst in every instance was a thin, mucoidal, yellow colored, odorless fluid. The esophagoesophageal or esophagogastric junction was in good condition in each case. Microscopic sections of the walls of the cysts showed an extremely thin layer of squamous epithelium backed by a layer of connective tissue and muscular tissue; there were no recognizable glandular elements (Fig. 2).

The formation of the cysts in Groups II and III dogs can be explained by adherence of the raw edges which came into contact. Dog 253, explored at

From the Department of Surgery of the Bowman Gray School of Medicine of Wake Forest College, and the North Carolina Baptist Hospital.
Received for publication Nov. 19, 1951.
*Trainee, National Cancer Institute.

TABLE I

TREATMENT OF ISOLATED SEGMENT	DOG NO.	POSTOPERATIVE DAYS AFTER ISOLATION OF SEGMENT	SIZE OF CYST (CM.)
Group I	250	12	4
(Both ends of	256	98	5
segment closed)	260	221	4
Group II	254	72	6
(Both ends of	255	128	6
segment open)	259	240	3
Group III	253	14	no cyst
(Segment split	258	110	4
lengthwise)	261	219	4

Fig. 1.—Photograph of esophageal cyst removed from Dog No. 256, ninety-eight days postoperatively.

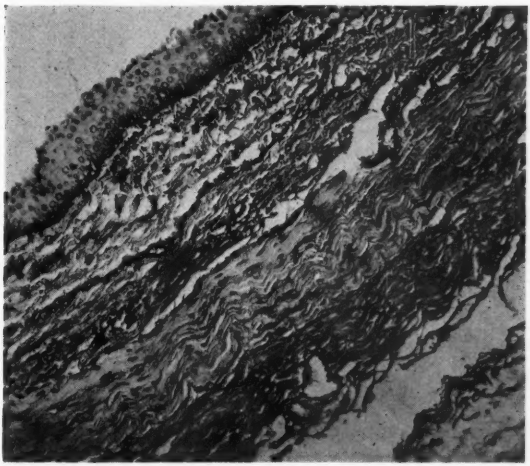

Fig. 2.—Photomicrograph of a section of the wall of the cyst shown in Fig. 1. The stratified epithelium, submucosa, and muscularis are plainly delineated, but there is a complete lack of glandular tissue. (Hematoxylin and eosin, ×95.)

fourteen days, had not had time to seal off the isolated segment. However, the segment had rolled on itself so as to form a tube. Undoubtedly the opposing edges would have become adherent within a matter of days.

DISCUSSION

From abroad physicians have reported the construction of side-tracking esophagogastric anastomoses, for circumventing strictured areas of the esophagus, in cases of lye strictures and carcinoma.[1-3] However, all cases reported have had the esophagus left intact, with performance of an intrathoracic side-to-side esophagogastrostomy. The leaving of the esophagus attached to the stomach makes it necessary to free up the stomach to a much more extensive degree than

Fig. 3.—Lateral chest roentgenogram following barium swallow. The esophagus is almost completely obstructed, and there is some overflow of the barium into the trachea.

simple isolation of the involved segment of the esophagus, but the authors apparently believe that the continuity is desirable for drainage. If cyst formation is to be averted, evidently drainage must be provided for. However, the fact that the animals in this experiment lived and did well, with no apparent injurious effects from the mediastinal cysts, indicates that the cyst formation may not be detrimental. Apparently the size of the cyst is self limited, for as the pressure in the cyst increases, the secreting glands atrophy and the size of the cyst becomes stationary. Otherwise, a cyst removed from a dog twelve days postoperatively (dog 250) would not be the same size as a cyst removed from

a dog 221 days postoperatively (dog 200). Thus the supposition that the isolated segment might become of tremendous size and so adversely affect the respiratory and circulatory functions is apparently baseless. Further, in patients who have advanced carcinoma of the esophagus in whom a palliative side-tracking procedure is planned, a mediastinal cyst is of no consequence.

CLINICAL APPLICATION

Since completion of the above work, one patient has presented himself for treatment of far-advanced carcinoma of the esophagus. The protocol is as follows:

J. W. A., a 65-year-old farmer, was admitted to the North Carolina Baptist Hospital on May 23, 1951. At that time he gave a history of having regurgitated some watermelon eight months previously. Soon after that, solids began to be intermittently regurgitated,

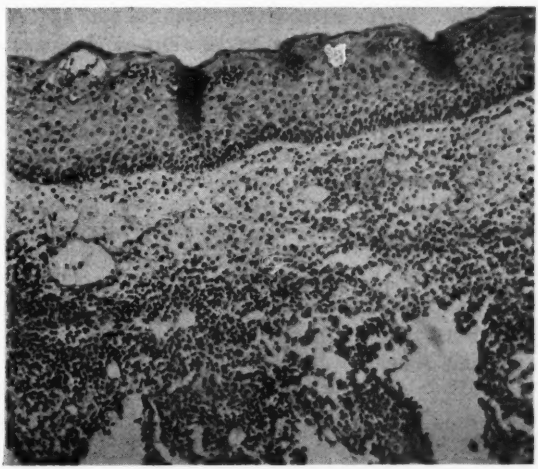

Fig. 4.—Photomicrograph of biopsy specimen. Note the intact epithelium, beneath which the submucosa and muscularis are infiltrated with carcinoma. (Hematoxylin and eosin, ×95.)

and for the month before admission he had been unable to eat any solid food. Although his appetite had remained excellent, he had lost about 60 pounds in weight since the onset of the illness. In April a roentgenographic examination of the esophagus was performed, and revealed a filling defect with almost complete obstruction in the midesophageal region (Fig. 3). He was subsequently referred to the North Carolina Baptist Hospital for therapy. Physical examination showed an elderly gaunt man who was quite pleasant and cooperative. Blood pressure was 130/80. There was evidence of considerable weight loss, but no other positive findings. Accessory clinical findings demonstrated no abnormality. Esophagoscopy was performed, and at 30 cm. from the upper incisor teeth was found a fungating easily bleeding mass which completely encircled the esophagus. Biopsy showed anaplastic carcinoma (Fig. 4). The following day left thoracotomy was performed. A hard, irregular growth was found to circumscribe the esophagus at the arch of the aorta. The growth was firmly fixed to the aorta, trachea, and prevertebral fascia. Enlarged lymph nodes were present above and below the tumor. It was impossible to free up the esophagus without risking an exsanguinating hemorrhage, and, as a cure was impossible, it was decided to leave the growth in place and construct an esophagogastric anastomosis around it. This was easily

done without undue incident. Postoperatively he did quite well, being able to take water by mouth on the first postoperative day, a full liquid diet on the third postoperative day, and a soft diet on the fifth day. Fluoroscopy on the tenth day showed the esophagogastric anastomosis to be functioning well, with no widening of the mediastinum indicative of fluid accumulation in the isolated segment of the esophagus. He was discharged on the twelfth postoperative day. At home he continued to enjoy eating, and gained weight.

CONCLUSIONS

In dogs it has been shown that isolation of a strictured segment of the esophagus produces a cyst, regardless of the treatment accorded the segment. The size of the cyst is apparently self limited, being regulated by the amount of pressure in the cyst, as the pressure causes atrophy of the secreting glands. The presence of a small mediastinal cyst did not adversely affect any of the dogs. Clinically, it is believed that all cases of carcinoma of the esophagus, unless distant metastases are demonstrated, should be explored. If the lesion is found to be too extensive for a curative procedure, and unfortunately a great number are, then a palliative esophagoesophageal or esophagogastric anastomosis appears to be indicated. This is a relatively short procedure, and will allow the patient to eat normally for the remainder of his life. Death from the complications of extension of the cancer is easier on the patient and his family than starvation. Gastrostomy gives no satisfaction to the patient, and is difficult to attend to.

SUMMARY

Isolation of a segment of the esophagus in the dog results in a small asymptomatic esophageal cyst. Such a procedure was performed on one patient, with quite satisfactory results. However, post-mortem studies on long-term survivors will be necessary before one can conclude that the operation is as satisfactory in human beings as in dogs.

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PULMONARY TUBERCULOSIS FOLLOWING RESECTION FOR NONTUBERCULOUS DISEASE

EMIL ROTHSTEIN, M.D.,* AND CHARLES E. GERSON, M.D.**
DAYTON, OHIO

IN THE past two decades, during which excisional surgery for pulmonary lesions has been performed with increasing frequency, there have been many articles dealing with techniques, indications, and results. Immediate and early complications arising after resection have been stressed. One late complication or sequel has received very little emphasis in medical literature. This is the delayed development of pulmonary tuberculosis. The occurrence of two such cases in our experience and the rapidly progressive nature of the disease in both patients aroused our interest in this problem. In addition, the coincidental finding in several patients of pulmonary tuberculosis and nontuberculous bronchiectasis led us to re-evaluate our therapeutic indications when these two disease processes both are in need of treatment.

CASE 1.—L. A. C., aged 30 years, had several attacks of hemoptysis and pneumonia in 1941, 1945, and 1947. Bronchograms (Fig. 1) showed definite bronchiectasis involving the superior segment of the right lower lobe. Right lower lobectomy was performed uneventfully in September, 1947. Sputum examinations before surgery failed to reveal tubercle bacilli, nor were tuberculous changes present in the resected specimen. Subsequent roentgenograms in 1947 showed no evidence of pulmonary tuberculosis. A roentgenogram in November, 1948, showed infiltration in the remainder of the right lung, which rapidly progressed to cavitation and extensive consolidation (Fig. 2, April 27, 1949). Sputum specimens were repeatedly positive for tubercle bacilli. Despite five months of streptomycin therapy, the disease remained largely unchanged. On Feb. 3, 1950, the rest of the right lung was removed. Far-advanced tuberculosis was found in the resected lung. After a protracted course characterized by empyema, tuberculous pericarditis, and contralateral pleural effusion, the patient expired on Aug. 24, 1951.

CASE 2.—B. M., 25 years of age, had left lower lobe bronchiectasis since 1943 (Fig. 3, Jan. 16, 1946). Left lower lobectomy was done in April, 1947. Sputum examinations before surgery failed to reveal tubercle bacilli; no tuberculous changes were found in the resected specimen. Postoperative films revealed no evidence of pulmonary tuberculosis. A subsequent roentgenogram in April, 1948 (Fig. 4), showed far-advanced tuberculosis in the left upper lobe. The patient was treated with streptomycin, and a left thoracoplasty was performed in August, 1948. He is still seriously ill with active disease in the other lung.

DISCUSSION

The only article we could find dealing directly with this subject was by Katz.[1] He reported four cases in which resections were done for bronchiectasis, sarcoid granuloma, and actinomycosis. In each of these cases sputum studies

From the Tuberculosis Service, Veterans Administration Hospital, Dayton, Ohio, and the College of Medicine, University of Cincinnati.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are the result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Received for publication Nov. 23, 1951.

*Chief, Tuberculosis Service, Veterans Administration Center, Dayton, Ohio, and Instructor in Internal Medicine.

**Attending Physician, Tuberculosis Service, Veterans Administration Center, Dayton, Ohio.

Fig. 1.—(Case 1, Sept. 26, 1947.) Bronchogram revealing saccular bronchiectasis in the dorsal division of the right lower lobe bronchus.

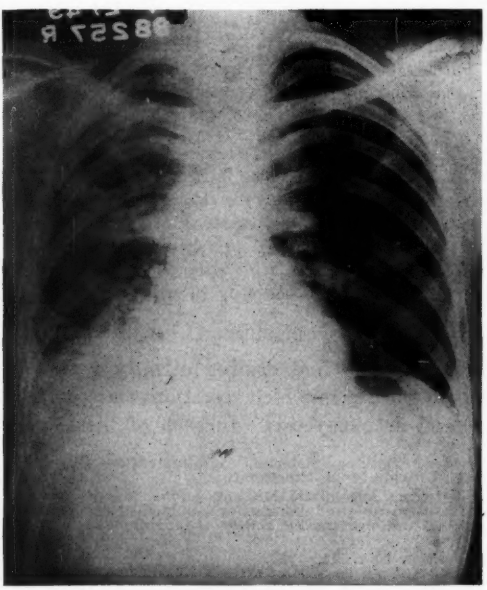

Fig. 2.—(Case 1, April 27, 1949.) Far-advanced pulmonary tuberculosis, involving right upper and middle lobes.

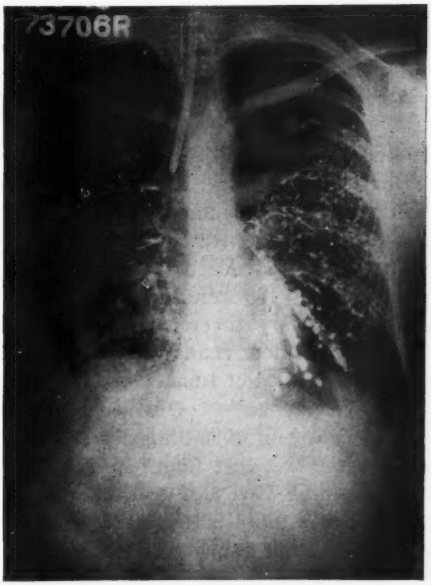

Fig. 3.—(Case 2, July 16, 1946.) Bronchogram revealing extensive saccular bronchiectasis in the basal divisions of the left lower lobe.

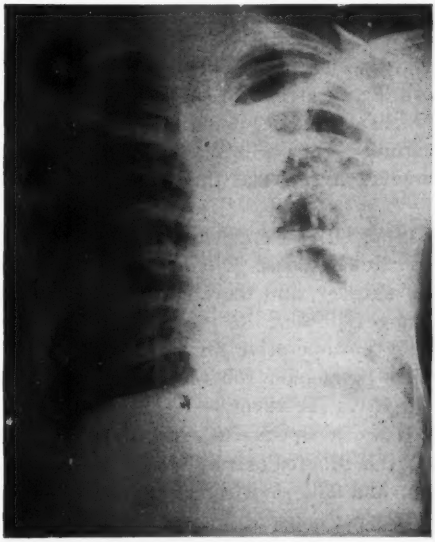

Fig. 4.—(Case 2, April 21, 1948.) Far-advanced pulmonary tuberculosis in the left upper lobe.

prior to resection were negative for tubercle bacilli, and the resected specimens showed no evidence of tuberculosis. Postoperative roentgenograms failed to reveal pulmonary tuberculosis. In the three cases having had lobectomy performed, far-advanced caseocavitary disease appeared in the remaining lobe in less than one year after resection. Our two patients presented exactly the same picture.

Other reports dealing with this subject have been buried in statistics pertaining to resections for bronchiectasis. Thus Maier[2] reported on sixty-four cases treated by resection. Active pulmonary tuberculosis developed in two patients. One of these had had inactive tuberculosis before surgery, and the other had shown no previous evidence of pulmonary tuberculosis. Sellors, Thompson, and Qvist[3] reported 100 resections for bronchiectasis. Seven of these patients developed pulmonary tuberculosis. Four of the resected specimens revealed evidence of tuberculous changes in addition to the bronchiectasis. Three of the seven patients had died of tuberculosis at the time of their report. Lambert[4] reported seventy-eight cases, of which ten developed pulmonary tuberculosis. The serious nature of this clinically evident tuberculous disease was shown in his series by the fact that four required thoracoplasty, two have died, and of the eight remaining alive, five still had positive sputa at an unspecified interval after resection. Six of these ten cases developed within one year after resection and the other four from sixteen to thirty months postoperatively. In four of the postlobectomy cases the disease developed in the remaining portion of the homolateral lung, as in Katz' series and in our cases.

Despite this very appreciable incidence, the subject has apparently aroused but little interest. This was shown in part by the fact that none of the discussants of Lambert's paper[4] commented upon the high incidence of this very serious complication.

The exact pathogenesis of the tuberculous lesion is of course impossible to state. The reason for any given patient developing pulmonary tuberculosis is such a compound of bacteriologic, immunologic, and mechanical factors that in the small groups studied the possibility of coincidence cannot be ruled out. Certain features, however, suggest that this is not the case in the subject under discussion.

In almost every reported case, review of the preoperative films showed no evidence of pulmonary tuberculosis. None of the authors refers to his gross findings at the time of surgery, and there is nothing to suggest that there were gross tuberculous changes present in the unremoved lung tissue remaining after lobectomy. Early postoperative films similarly failed to reveal shadows typically associated with pulmonary tuberculosis. Sputum examinations, whenever reported, were negative for tubercle bacilli, and in most instances pathologic examination of resected specimens showed no evidence of tuberculosis.

In our two cases the tuberculosis appeared on the side which had been subjected to resection, and did so within one year of surgery. The disease rapidly became far advanced and did not respond to medical measures. Katz' three postlobectomy cases followed exactly the same pattern, as apparently did four of Lambert's patients.

Several possibilities for the development of tuberculosis in this group must be considered. Coincidence has been mentioned but should probably be rejected. Lowered resistance due to chronic infection or due to the surgery must be mentioned as a possibility and can in no case be completely discounted. Undetected tuberculosis may have been present in the lobe removed and the disease may have been spread to the remaining lung parenchyma at operation. That this is unlikely seems evident from the fact that postoperative examination of resected specimens failed, in most instances, to reveal tuberculous changes. If sufficient caseation and cavitation were present to produce such a spread, they could hardly escape detection by the pathologist. Other circumstances mitigating against this hypothesis are the negative sputum examinations for tubercle bacilli before and after surgery and the delayed (six to twelve months) appearance of the tuberculous lesions. Postoperative spreads following surgery for pulmonary tuberculosis usually are noted in the immediate or early postoperative period.

Tuberculous disease may have been present in the hilar structures, and if such tissue were cut across at surgery, this might explain the late development of tuberculosis in the adjacent lung. This hypothesis was advanced by Sellors, Thompson, and Qvist,[3] and is discussed by Lambert.[4] The use of individual ligation at the bronchial stump will presumably make unlikely section of grossly involved tuberculous nodes or other tuberculous tissue without immediate discovery by the surgeon.

Distention of remaining pulmonary tissue, containing hidden unhealed tuberculous foci must be very strongly indicted as the most probable cause for the phenomenon under discussion. We were unable to find any experimental proof that distention of such lung tissue might actually result in progression of a latent tuberculous process. There are, however, clinical grounds for such an assumption. One of these is the beneficial effect upon an active tuberculous process of a decrease in pulmonary volume and tension, as provided by pneumothorax, phrenic nerve surgery, pneumoperitoneum, and thoracoplasty. While these methods of treatment may exert their therapeutic effects in various ways, one of the most important of these is by the opposite of overdistention, i.e., by relaxation of the involved pulmonary tissue. It is therefore reasonable to assume that overdistention may, in some cases, delay healing and predispose to progression of disease. This factor is recognized in the generally accepted practice of performing thoracoplasty after upper lobectomy or pneumonectomy for pulmonary tuberculosis, to avoid overdistention of the remaining lung tissue.

We have allowed the clinical material and theoretical considerations presented above to assist us in formulating certain tentative indications for the treatment of patients who present roentgenographic evidence of pulmonary tuberculosis in addition to some other disease requiring excisional surgery of a lobe or lung. These indications are based upon two features. One of these is the need to consider the tuberculous condition as potentially serious, if it is present in lung tissue which will be subjected to postresection distention. The other is based upon the work of Baum and Baum.[5] These authors showed

that the coincidental presence of a suppurative pneumonia and tuberculosis often resulted in a harmful effect upon the tuberculous process. They found that when a suppurative pneumonia (such as is commonly associated with chronic lung abscess, bronchiectasis, bronchostenosis, etc.) was present in the same lobe as the pulmonary tuberculosis, 70 per cent of the tuberculous lesions were unfavorably influenced. When the processes were present in different lobes the incidence of reactivation or spread of the tuberculosis was less, but a suppurative pneumonitis apparently may exert a harmful effect upon pulmonary tuberculosis wherever situated. We consider the Baums' work to favor the principle of excising pulmonary suppurating or obstructive lesions coexisting with pulmonary tuberculosis, when this can be done without causing overdistension of the tuberculous areas.

The indications formulated below are, of course, tentative only, since they are based on an admittedly small amount of clinical material.

1. The principle of conservation of normal lung tissue should always be adhered to. Segmental resection when feasible should always be preferred to lobectomy.

2. When inactive pulmonary tuberculosis is present steps should be taken to avoid overdistention of the tuberculous area. Thus after lower lobe resection, phrenic paralysis possibly associated with a period of pneumoperitoneum would be desirable. If the lesions coexist in the same lobe, this should be considered a further indication for resection.

3. In the presence of active pulmonary tuberculosis, distention of the tuberculous area must be regarded as potentially very dangerous. If the disease processes can be excised at the same operation this should again be considered a positive indication for lobectomy or pneumonectomy. When the disease processes are bilateral we feel that prolonged sanatorium treatment of the tuberculous process with appropriate chemotherapy should be the method of choice.

Since this study was begun, three patients with bilateral lower-lobe bronchiectasis and active upper-lobe tuberculosis have presented themselves for therapy. In each case, in the absence of a tuberculous lesion, segmental resections or lobectomies would have been performed for the bronchiectasis. Guided by the above principles, however, each patient was treated with chemotherapy (consisting of 1 Gm. streptomycin twice weekly and 12 Gm. PAS daily) for prolonged periods of time (eight to eighteen months) with clinical arrest of the tuberculous lesion and marked improvement in the symptoms of bronchiectasis.

CONCLUSIONS

Pulmonary tuberculosis occurs as a sequel with impressive frequency in patients who have had resection for nontuberculous disease, even in the face of negative roentgenograms and bacteriologic studies for tubercle bacilli in the immediate pre- and postoperative periods. In several series the reported incidence varied from 3 to 13 per cent. This finding leads to the conclusion that this is a group needing periodic follow-up roentgenograms in much the

same way as contacts to active cases of tuberculosis require follow-up. Routine chest roentgenograms every three months for one year after surgery and every six months for several years longer might prevent the tragic development of a tuberculous process already far advanced when first detected.

The exact pathogenesis of this tuberculous process is not known, but overdistention of the remaining lung tissue seems at present the most important single factor. Therefore, when pulmonary tuberculosis is known to coexist with some other disease requiring resection, overdistention should, if possible, be avoided. This may be effected by a combination of segmental resection whenever possible, with consequent conservation of lung tissue, and diminution in the size of the hemithorax by some combination of phrenic nerve surgery, pneumoperitoneum, thoracoplasty, etc. Such patients should in addition be followed with frequent roentgenogram examinations in order to discover any reactivation of the tuberculous process as soon as possible after its development.

SUMMARY

1. Two cases are presented in which far-advanced pulmonary tuberculosis developed in patients who had recently undergone lobectomy for bronchiectasis.

2. The literature on this subject has been reviewed.

3. In three reported series pulmonary tuberculosis has developed in from three to thirteen per cent of the patients.

4. All postlobectomy patients should be followed with frequent chest roentgenograms to detect the possible development of pulmonary tuberculosis.

5. When pulmonary tuberculosis is present in a patient requiring pulmonary resection for a nontuberculous disease, the surgery should be planned to avoid a situation conducive to overdistention of the tuberculous pulmonary tissue. Certain specific recommendations are given.

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SPONTANEOUS HEMOPNEUMOTHORAX

COLIN A. ROSS, M.D.
EDMONTON, CANADA

APPROXIMATELY eighty-four cases of spontaneous hemopneumothorax have been reported in the medical literature to date. The condition is therefore of relatively rare occurrence. The purpose of this paper is to record six more cases and to make certain suggestions regarding the treatment of the disease. One of the cases reported may be the first reported case of successful surgical intervention in the acute stage of the disease.

HISTORICAL

Recognition of the disease was probably first made by Laennec in 1828 who found air under pressure and blood present in the pleural cavity in a case at autopsy. Whittaker, in 1876, reported the successful treatment of a case by aspiration. The first two comprehensive case reports were, however, published in 1901, independently by Pitt[1] and Rolleston.[2] Each author published a single case report of fatal spontaneous hemopneumothorax. Both cases were young men. Pitt's case of an 18-year-old boy showed at autopsy emphysematous bullae at the apex of the right lung and torn pleural adhesions. Rolleston's patient, a 21-year-old man, was admitted with a perforated peptic ulcer but, due to his extreme degree of shock, he was not operated on. He improved for a few days, but died one week after admission. Autopsy showed a right hemopneumothorax, but no apparent source of the bleeding.

Of the reported cases, approximately 25 per cent have been fatal, and it is interesting to note in the fatal cases coming to autopsy, that there is remarkable absence of evidence of the source of the bleeding and a not uncommon finding of the presence of emphysematous bullae in the affected lung.

Hartzel[3] published an excellent paper on the subject in 1942, reviewing the literature and reporting two cases. One of his patients had suffered a spontaneous pneumothorax, with no evidence of effusion, two years previous to his admission with a spontaneous hemopneumothorax.

Since 1942 several papers on the subject have been published, bringing the number of reported cases to approximately sixty-five.

Of the number, three cases have been treated in the chronic phase of the disease by decortication,[4, 5, 6] and Hansen[6] reports an unsuccessful attempt to treat one case with a persistent fistula by thoracotomy, with intent to suture the ruptured bullae. These were too numerous to suture, and the patient later died of anoxia. There is, to my knowledge, no report of successful surgical treatment of the acute stage of the disease.

From The Newcastle-on-Tyne Regional Thoracic Surgery Center, England.
Received for publication Nov. 23, 1951.

INCIDENCE

The disease appears to be almost confined to males, there being only four female cases reported. This fact is difficult to explain. It has been suggested that men are more active than women and that muscular exertion is a causative factor in the rupture of a subpleural vesicle, producing the initial pneumothorax. However, this condition and its allied disorder, spontaneous pneumothorax, which is almost as common in women as in men, may appear when the patient is doing nothing more strenuous than shaving or, indeed, than reading the Sunday newspaper. It is thus doubtful if exertion is a very potent factor.

The average patient is between 20 and 40 years of age, and the right side is as frequently affected as is the left.

PATHOLOGY

The mechanism of production of the condition is most certainly that of rupture of a subpleural bulla with the production of a spontaneous pneumothorax. Vascular adhesions are torn, and the pleural space fills with air and blood. If the fistula remains patent and if a "ball valve" mechanism is present, a tension hemopneumothorax results.

Bronchiolar scarring due to previous inflammatory disease (e.g., tuberculosis) may well be a factor in the production of subpleural valve vesicles, which, on rupture, allow the continued escape of air into the pleural cavity. The inflammatory lesions are, however, practically always healed, and pathologically the blame cannot be definitely traced to tuberculosis as the antecedent infection. Congenital cystic lung is also a cause, although, from reports, it appears to be a rather infrequent one. It may be stated that unless there is obvious gross tuberculous cavitation present in the affected lung, it is reasonably safe to assume that active tuberculosis is not a factor in the production of the disease. It is recognized that there can be exceptions to every rule of this type, and routine sputum examinations are carried out in each case.

SYMPTOMATOLOGY

The onset may be acute and with dramatic suddenness, or it may be gradual and more insidious. In the acute stage there may be a sudden severe pain in the chest or upper abdomen, radiating to the neck and shoulder, and accompanied by syncope. There is next a latent period, in which the pain is less and the patient feels somewhat better. As the bleeding continues, shock and collapse occur. The escaping air builds up pressure in the pleural cavity and tension phenomena result. There may be nausea and vomiting due to irritation of the lower thoracic nerves with reflex via the sympathetic supply to the abdominal viscera. If the escape of blood and air is slower, the above symptoms will be less marked, and will appear over a period of hours or even days.

DIFFERENTIAL DIAGNOSIS

One of the first cases reported was misdiagnosed as a perforated peptic ulcer, as were three of this series, and it is probable that this is a not infre-

quent "first diagnosis." The disease very closely resembles such acute abdominal conditions as perforated viscus, acute pancreatitis, renal or choledochal calculus. The severe chest pain with radiation to the arm and shoulder, accompanied by shock, is very suggestive of coronary occlusion. The clinical evidence of pneumothorax is, however, usually quite obvious.

TREATMENT

It has been frequently suggested that the treatment in the acute stage of the disease, when active bleeding is present, should be that of bed rest, warmth, sedation and, if necessary, transfusion. Aspiration of the chest is advocated if the mediastinal displacement is great enough to cause respiratory embarrassment. The rationale of this treatment has been based on the belief that, as in intrapulmonary hemorrhage, rest, warmth, and sedation are beneficial, and that if the bleeding be from the lung, collapse of that organ will aid in the arrest of the hemorrhage. From observations at segmental lobectomy I would suggest that the latter part of this thesis is not entirely founded on fact, inasmuch as the bleeding tends to cease with the lung expanded.

On examination it seems that a mortality rate of 25 per cent is rather high for hemorrhage from a vessel of relatively minor caliber, and that active treatment might have been more successful than the "wait and see" attitude.

The treatment of this condition resolves itself into two phases: that of the "acute stage" and that of the "chronic stage" of the disease.

TREATMENT IN THE ACUTE STAGE

Clinically, the acuteness of onset will vary with the rate of accumulation of air and blood in the pleural space. Generally, however, shock and dyspnea due to blood loss and mediastinal displacement are fairly well marked. There are two problems in this phase: that of blood loss and that of interference with the cardiorespiratory function by the accumulation of blood and air in the thorax. The patient should be treated as an urgent surgical emergency. Posteroanterior and lateral roentgenograms of the chest should be obtained. Blood should be matched and equipment made ready for thoracentesis and the insertion of an indwelling catheter into the chest. The intrapleural tension must be relieved and the lung allowed to expand and obliterate the pleural space. This is best accomplished by an intercostal catheter of the Malicot type, attached to a water seal, and allowed to drain gradually over a period of several minutes. Transfusion should also be started at this time. Generally speaking, the patient's condition should be now, at least temporarily, under control, and one can observe the rate at which further bleeding occurs. It may be necessary to place another catheter in the second interspace anteriorly to allow air to escape, as the presence of dependant fluid is often an effective barrier to the escape of air except under considerable pressure. The catheter in the dependent drainage position may also be blocked by the partially expanded lung or by an elevated diaphragm. Serial roentgenograms will be necessary to determine the degree of expansion of the lung. It must

not be taken for granted that the lung is completely expanded, because air entry can be heard on auscultation over the affected side. It is important that every effort be made to prevent any residual space being left to require treatment at a later date. *"Now is the hour."* The patient is nursed in the semi-recumbent position unless in extreme shock, and oxygen is given as indicated.

If bleeding, as shown by the condition of the patient and the amount of drainage in the bottle, appears to be excessive and continuous, then no time should be lost in deciding upon a thoracotomy as the further "treatment of necessity." With the chest open and the bleeding point under direct vision,

Fig. 1.—(Case 1). Roentgenogram taken on admission. Note large pneumothorax, fluid level-apical adhesion. Note also the mediastinal shift to the left.

the problem becomes one of arrest of hemorrhage with the bleeding vessel conveniently accessible. When the space has been cleared of clot and the bleeding controlled the chest is closed, leaving two intercostal catheters attached to water seals. One tube is in the costophrenic angle and one in the second interspace anteriorly. No attempt need be made to close the fistula, if indeed it may be found, but large emphysematous bullae may be resected if the condition of the patient allows and the procedure is not too formidable. Postoperatively, every effort must be made to secure complete expansion of the lung.

That the results of the above schedule of treatment may be expected to be favorable is illustrated by the following case.

CASE 1.—Shotley Bridge No. 6441, male machinist, 34 years of age. This patient was admitted with a history of having been seized with a sudden sharp pain in the right posterior chest while at work twenty-four hours previously. About sixteen hours prior to admission he had vomited undigested food, a considerable quantity of "coffee ground" material, and about a dessertspoonful of bright red blood. He had no further vomiting. He volunteered the information that he had suffered from "stomach trouble" for years. Since the onset of pain he had become somewhat short of breath, but not markedly so. He also had had several bowel movements, but no evidence of melena. On examination he was pale, breathing rapidly, but was not distressed. His pulse was 120 per minute and his blood pressure was 70 mm. systolic. One hour after admission a blood transfusion was started. The diagnosis at that time was that of gastrointestinal hemorrhage, but six hours later the patient suddenly collapsed, was cyanosed and dyspneic, and had the signs of a tension pneumothorax. Aspiration of the chest at this time yielded air and a small amount of blood, and gave immediate relief of

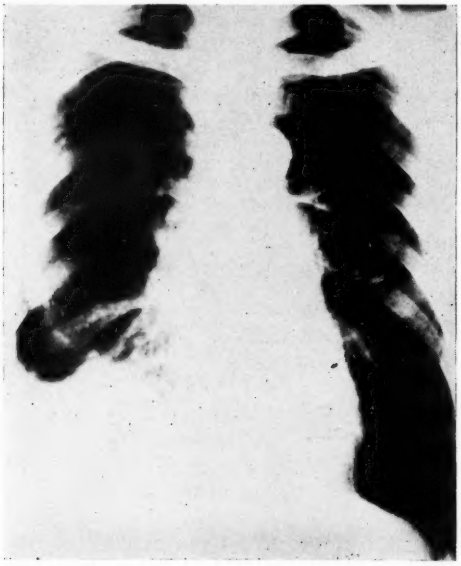

Fig. 2.—(Case 1.) Roentgenogram made at outpatient department, showing satisfactory re-expansion of the lung following thoracotomy. There are residual adhesions at the costophrenic and cardiophrenic angles.

symptoms. However, it was again necessary to aspirate the chest half an hour later, and two and one-half pints of blood were removed at this time. At this stage the patient was in extreme shock and death seemed imminent. However, by transfusing under pressure and the introduction of an intercostal catheter, he improved remarkably, and within a few hours he seemed comparatively well. Blood, however, continued to drain from the pleural space, and his condition again began to deteriorate. It was obvious that he was not going to survive unless the bleeding could be stopped. He was accordingly removed to the operating theater and a *quick* thoracotomy was performed. A large amount of clotted blood was removed from the pleural space and a partially divided adhesion was seen at the apex of the lung. In this adhesion was a small, actively bleeding artery. The opening in the artery was obviously being kept patent by the tension of the adhesions. A small bulla was also present. The division of the adhesion was completed, and the vessel was ligated. The chest was then

rapidly closed, with intercostal drainage. From this point the patient improved very rapidly, and by the next day he appeared no different from any ordinary thoracotomy case. The lung re-expanded without difficulty, and the convalescence was uneventful.

TREATMENT IN THE SUBACUTE OR CHRONIC PHASE

At this time the bleeding has ceased, the fistula has usually closed, and the patient is partially adjusted to the mediastinal displacement. The problem is now one of securing re-expansion of the lung. This is complicated by the deposition of fibrin on the pleural surface as a result of defibrination of the blood in the pleural space by the motion of the heart and lungs. If the time elapsed is short (less than one week) the task is easier as the layer has not yet begun to organize. Organization proceeds rapidly from this time onward and by a month the layer contains well-formed "adult type" fibrous tissue.

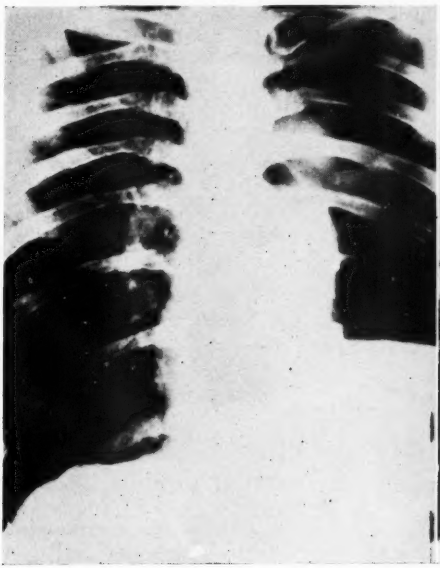

Fig. 3.

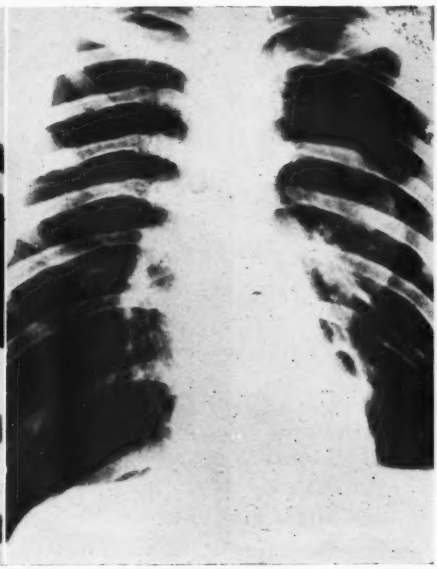

Fig. 4.

Fig. 3.—(Case 2.) Roentgenogram taken on admission, showing large pneumothorax and fluid level.

Fig. 4.—(Case 2.) Roentgenogram one month after admission. Note that the lung is still only partially expanded, and that a fluid level is still present.

In the early case one may attempt to secure re-expansion of the lung by means of repeated aspiration, saline washouts, and perhaps the use of streptokinase. This method works well, even in cases that are not so early, as is shown by the following examples.

CASE 2.—Middlesborough Chest Clinic No. 1, male laborer, aged 26 years. This man was admitted with a three-week history of pain in the left posterior chest, and gradually increasing weakness and dyspnea. He eventually became too weak to get out of bed. On admission he was quite ill, very short of breath, cyanotic, and febrile. The roentgenogram showed

a large left hydropneumothorax which on aspiration yielded air and dark brown fluid which was found to be old blood. Six pints of this were removed from the chest. Repeated aspirations, combined with saline washouts, resulted in complete re-expansion of the lung in three months' time.

CASE 3.—Middlesborough Chest Clinic No. 2, male post office engineer, 29 years of age. This patient developed severe pain in the left chest and shortness of breath while seated at his office desk. Later in the day he vomited repeatedly. He was treated expectantly by his doctor, and the pain gradually eased and the dyspnea became less. Three weeks later, when he had been ambulatory for about five days, he again experienced a sudden attack of chest pain and dyspnea. Chest aspiration at this time revealed the presence of a left hemopneumothorax. He was treated by repeated aspiration of the chest and re-expansion of the lung was progressive over the following six weeks.

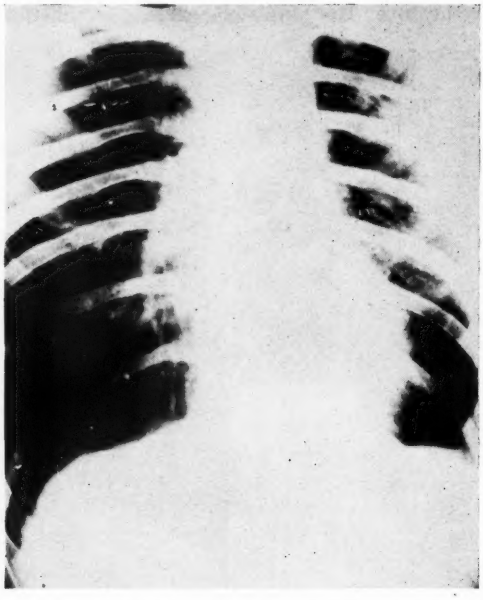

Fig. 5.—(Case 2.) Roentgenogram showing satisfactory re-expansion of the lung six months after admission.

It may be seen from the examination of these two cases that, although the results were those of complete expansion of the lung with a good functional result, the time necessary to achieve this result may be as long as three months, and it must be remembered that the risk of converting a simple clotted hemothorax into an empyema is always present.

Of the next two cases, one was first seen in the acute stage and the other in the chronic stage. Both were treated conservatively by aspiration and transfusion in the acute stage until the bleeding had ceased and the fistula was closed. In each case there remained a residual space. This was treated for a short while by further aspiration but it could be seen that cure by this

method was going to be a slow process. It was thus decided to try to produce a surer and faster result by decortication. This was done with good results in both instances.

CASE 4.—Poole Sanatorium No. 3063/3720, male tool maker, 22 years of age. This man had a sudden attack of dyspnea and of pain in the epigastrium on the morning of Dec. 15, 1949. He was admitted to a general hospital the same day, and a laparotomy was performed with the preoperative diagnosis of perforated duodenal ulcer. He was then found to have a large left hemopneumothorax. This was treated by repeated aspiration during the following

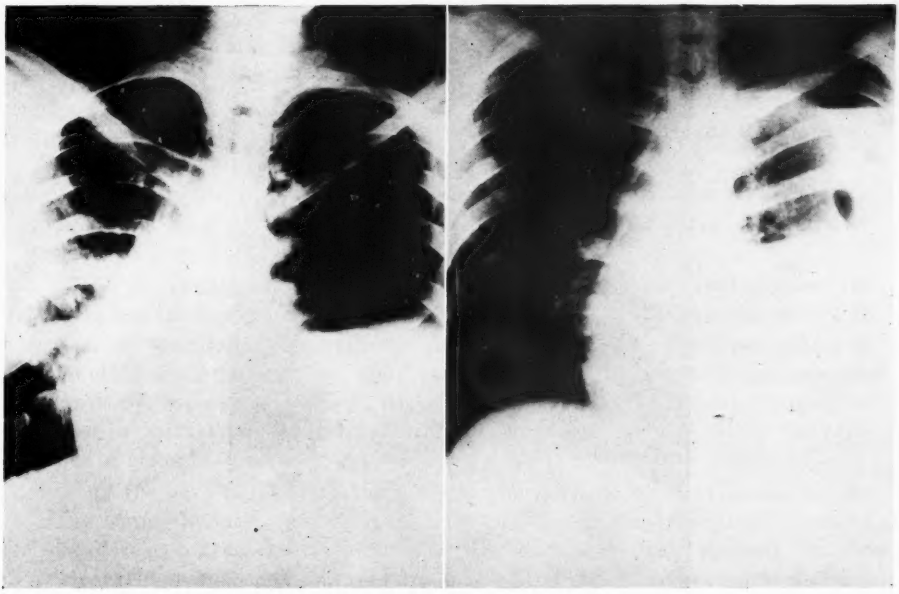

Fig. 6. Fig. 7.

Fig. 6.—(Case 5.) Roentgenogram taken on admission. Note large tension hydropneumothorax with marked mediastinal shift.

Fig. 7.—(Case 5.) Roentgenogram before decortication. Note partially expanded lung and multiple intrapleural fluid levels.

two weeks. He was then transferred to Poole Sanatorium where further aspirations and saline washouts were performed. It was soon decided that the lung was too bound down by organizing fibrin clot to re-expand quickly, and on Jan. 17, 1950, decortication was carried out. Two intercostal drains were left in the pleural space postoperatively. Within two weeks the lung was almost completely expanded, and further convalescence was uneventful.

CASE 5.—Shotley Bridge No. 0274, male Norwegian sailor, aged 25 years. This man was admitted to Shotley Bridge Hospital with a history of having developed a sudden sharp pain in the left chest while pulling on a rope. A few minutes later he became short of breath and he collapsed. On admission, several hours later, he was ill, pale, dyspneic, and in shock. Roentgenogram showed a large left hydropneumothorax. A needle was inserted into the chest and left attached to a water seal as an emergency measure. A large amount of air bubbled out, with immediate improvement in the patient's condition. Shortly

afterward 6 pints of almost pure blood were aspirated from the pleural cavity. Blood transfusion was commenced, and within a short time the patient's condition was quite good. Further aspirations were performed over the following few days. Two weeks after admission, a roentgenogram of the chest showed a partially expanded lung with multiple fluid levels intrapleurally. In this case, it is probable that if early intercostal drainage had been used instead of aspiration, the lung would have fully expanded. It was finally decided that decortication should be performed, and, following this operation, the lung re-expanded satisfactorily and the man was discharged three weeks after operation.

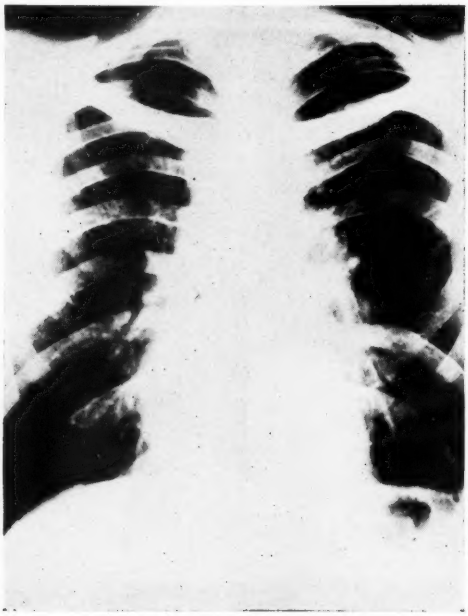

Fig. 8.—(Case 5.) Predischarge roentgenogram showing satisfactory re-expansion of the lung.

If the patient is seen at the time when organization of the fibrin layer has already begun, the treatment of choice is thoracotomy and decortication of the lung. If, even in an early case, there is a large amount of clot in the pleural space, the same rule applies.

The last case was first seen some months after the onset of his illness. He presented with a definite organizing clotted hemothorax. This man was unusual, in that he gave a long history of "chest trouble" with repeated attacks of bronchitis and "chest colds."

CASE 6.—Shotley Bridge No. 6995, male shoolteacher, aged 26 years. Three months prior to admission this man developed a sudden pain in the right chest and became short of breath. He was treated as a "pleurisy" patient until his distress became so great that he had to be admitted to the hospital where a roentgenogram revealed the presence of a large right hydropneumothorax. Aspiration was performed, and 18 ounces of dark blood were

obtained. As it was evident that the pleural space was filled with organizing blood clot, it was decided to transfer him to Shotley Bridge Hospital for treatment. On admission there he was a thin, pale, tired, and ill-looking young man. After transfusion and several days on a high protein diet, his condition improved considerably. It was therefore decided to decorticate his right lung. At operation a large amount of organizing blood clot was removed from the pleural space, and a moderately thick fibrous "peel" was stripped from the surface of the visceral pleura. The lung expanded well postoperatively, and subsequent bronchography showed no evidence of the bronchiectasis that had been suggested by his history. Seen recently at the outpatient clinic, he had gained approximately 30 pounds in weight since the operation, and stated that "he had not felt as well for years as he did then."

In none of the cases operated on in the chronic stage was there seen any evidence, at operation, of the cause of the pneumothorax.

DISCUSSION

From consideration of the above cases, it is obvious that the logical treatment of this condition can be summarized as follows.

In the acute stage the procedure should be to decompress and drain the chest with an intercostal catheter attached to a water seal, transfuse, and be prepared to do a thoracotomy if necessary.

In the early chronic stage (up to one week), before organization of the fibrin has started, intercostal drainage and intensive physiotherapy should be used. If the fistula remains persistently open and the lung will not adhere to the chest wall, thoracoscopy and "poudrage" with iodized kaolin or asbestos powder is indicated. Usually, however, a pleuritis of sufficient intensity to close the fistula and produce pleural adhesion will be produced by the presence of blood in the pleural cavity.

If the case goes on to the late chronic stage without expansion of the lung being obtained, or if the patient is first seen in the late chronic stage of the disease, a thoracotomy with decortication of the lung is advised. In the case, early or late, with a large amount of clotted blood in the pleural space, it is advisable to do a thoracotomy and to clear out the clot to enable the lung to expand properly.

CONCLUSION

Six cases of spontaneous hemopneumothorax have been discussed, and a program of therapy has been outlined for the treatment of this condition.

I would like to thank Mr. George A. Mason, F.R.C.S., the Director of The Newcastle-on-Tyne Regional Thoracic Surgery Centre, Dr. Robt. Cunningham, Physician Superintendent of Poole Sanatorium, and Dr. Walton, Chest Physician of the Middlesborough Chest Clinic for their help and encouragement in the preparation of this paper, and for permission to publish details of cases under their care.

ADDENDUM

Since this paper has been compiled I have had a communication from Mr. John Borrie, F.R.C.S., the assistant surgeon in the Department of Thoracic Surgery, Green Lane Hospital, Aukland, New Zealand. He informs me that he has recently performed thoracotomies, in the acute stage of the disease, on two patients with spontaneous hemopneumothorax. The results in both instances were good.

It has also come to my attention that an article by Myers, Johnston, and Bradshaw, reporting the successful treatment by thoracotomy of an acute case of spontaneous hemopneumothorax, appeared in the *Annals of Surgery* of March, 1949. The case reported by me is therefore not the first one.

The above additional evidence supports the suggestion that thoracotomy is a good form of treatment of selected cases of the disease.

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THE DEVELOPMENT OF CANCER IN DYSTOPIC AND ECTOPIC THORACIC STOMACHS

Report of Two Cases

George T. Pack, M.D., Frank S. Butler, M.D., and Elihu Katz, M.D.
New York, N. Y.

THE incidence of intrathoracic gastric carcinoma is low There is a paucity of medical literature on this subject. The bizarre association of gastric cancer in a partial or complete intrathoracic stomach is probably more frequent than reports would indicate for three reasons: (a) many cases are not reported, (b) the diagnoses are not accurate due to pre-existent and coexistent symptoms and radiographic abnormalities, and (c) a large proportion of the case reports are based on clinical evidence unsupported by surgical confirmation. We wish to report two instances of resectable gastric cancer occurring within the chest and characterized by the following facts: Case 1.—Laparothoracotomy and subtotal esophagogastrectomy with intrathoracic esophgogastric anastomosis; Case 2.—A remarkable instance of cancer in a thoracic stomach, treated by total gastrectomy and intrathoracic esophagoduodenostomy (first recorded instance).

Incidence.—The annual American death rate from cancer in general approaches 125 per 100,000 of population, and for cancer of the stomach perhaps 20 per 100,000 of population, which means an estimated 28,000 deaths yearly due to gastric cancer. Among 1,200 cases of carcinoma of the stomach directly involved in the experience of one of us (G. T. P.), there have been only two instances of its occurrence within a partial or complete intrathoracic stomach, an incidence of 1 to 600, or 0.166 per cent. The theoretical application of this ratio on a national scale would suggest that about forty-five cases of cancer in an intrathoracic segment or entire stomach should be expected yearly in the United States. As far as we can determine in a casual review of the world literature, there may not have been more than twenty to twenty-five such cancers successfully resected in all times. The ratio of cancers occurring in intrathoracically dystopic or ectopic stomachs leads to interesting speculation concerning statistical and etiologic relationships. In an experimental screening by routine gastrointestinal roentgenographic examinations of some 4,000 apparently normal American men and women over 40 years of age, Robert Sherman detected only six well-defined diaphragmatic hernias and about twenty small hiatus hernias, suggesting a ratio of approximtely 600 per 100,000 of population, a figure well below that of many reporters whose criteria are not so critical of the degree of herniation, e.g., Brick with 308 hernias found in 3,448 routine gastrointestinal roentgenographic examinations (7,500 per 100,000 of population). Utilizing the figures of Sherman, we can say from our own data that, (a) there are about 300 cases of diaphragmatic hernia existing for

Received for publication Nov. 27, 1951.

every cancer of the gastric cardia, (b) only one in sixty cancers of the gastric cardia occurs in an intrathoracic stomach, and (c) the theoretical likelihood of a patient with a diaphragmatic hernia developing cancer within the intrathoracic segment of the stomach is about one in 180,000 cases.

Anatomic Relationships and Criteria.—The employment of the term diaphragmatic hernia indicates that all such dystopic stomachs have an investiture of a hernial sac, in contradistinction to a false hernia or "evisceration." The phrase "hernia of the diaphragm" is not generally used in the case of the congenitally short esophagus because it suggests that the stomach was sometimes within the abdominal cavity. It would be more proper to say "thoracic stomach," but even this term implies that the entire stomach is in the chest; at least it distinguishes it from congenital absence of the diaphragm when both the stomach and intestines are in the thorax. Numerous names have been suggested for this interesting abnormality including: (1) thoracic stomach, (2) hiatus hernia with congenitally short esophagus, (3) diaphragmatic hernia of the short esophagus type, (4) partial thoracic stomach, (5) congenital shortening of the esophagus and the thoracic stomach resulting therefrom, and (6) eventration of the diaphragm (this refers to a highly placed but intact diaphragms. As far as we know, Percival Bailey first employed the term "thoracic stomach," to designate the congenital development of the stomach above the diaphragm, in which case there would be no false opening in the diaphragm, whereas in the case of diaphragmatic hernia the stomach in whole or in part may be constantly or intermittently within the chest and may be accompanied by other organs. Maurice Feldman's criteria for a true thoracic stomach are: (a) the esophagus opens into the stomach above the diaphragm, (b) no stream of barium representing the abdominal esophagus is seen to pass below the diaphragm, (c) the esophagus is not distorted or curled back on itself, and (d) the stomach remains above the level of the diaphragm and the esophagus is too short to reach the level of the diaphragm. The two case reports presented here probably represent both types; e.g., Case 1 is suggestive of cancer of the gastric cardia developing in the segment of the stomach participating in a diaphragmatic hernia (dystopic stomach); Case 2 in spite of its envelopes, is typical of a congenitally short esophagus with total intrathoracic stomach and normal diaphragmatic hiatus traversed by an attenuated duodenum.

Etiologic Considerations.—Can one say that a diaphragmatic hernia containing a dystopic stomach or a congenital intrathoracic (ectopic) stomach are causal factors leading to the genesis of cancer in these involved parts or should it be assumed that the two diseases are coincidental in their regional localization? The arguments may be summarized briefly:

1. The previously mentioned data concerning the relative incidence of diaphragmatic hernia and gastric cancer and their coexistence in the same patient would discourage any thought of causal relationship.
2. The stomachs involved in these displacements obviously could be involved by the same diseases and with the same frequency as occurs in stomachs of otherwise normal individuals in the same age groups.

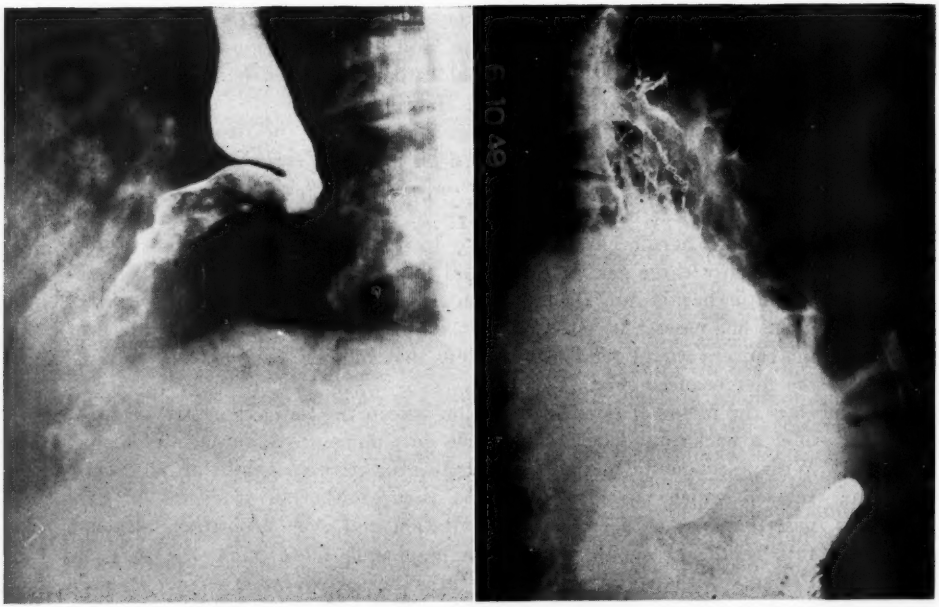
In Brick's series of 308 patients with hiatus hernias, the following associated lesions were found: duodenal ulcer, 31; esophageal diverticulum, 5; esophagitis, 3; hypertrophic gastritis, 7; gastric ulcer, 1; esophageal cancer, 1; gastric cancer, 4 (of which only two were confirmed by operation).

3. The coexistence of gastric cancer and dystopia or ectopia of the stomach should not be significant unless the cancer was situated in the herniated segment of the stomach. As a matter of fact, quite a number of the gastric cancers reported to be associated with hiatus hernias were pyloric in site (Schwartz, Jackson, and Harrington) and some of the coexistent cancers were esophageal rather than gastric in histogenesis (Hill, Wolf, Smithers, Olsen, and Harrington).
4. Do these cancers develop on ulcers occurring in the displaced or malplaced gastric segment? The assertion has been repeatedly quoted that the congenitally short esophagus is commonly associated with peptic ulceration. The common occurrence of gastric hemorrhages in patients with hiatus hernia has lent support to this theory. Nevertheless, Polley found only three gastric ulcers and no cancers in his forty-seven cases of hiatus hernia and Brick reported one gastric ulcer and four cancers in his 308 cases. In our two reported cases, the gross configurations of the cancers would render it unlikely that in their origins, they were of the ulcerocancer type.
5. Does the factor of possible irritation within the thoracic gastric segment offer a background or basis for the development of cancer in this site? With a congenitally short esophagus, the cardiac sphincter is usually relaxed which may predispose to regurgitation or retention of acid gastric juices with consequent irritation and even ulceration, although this condition should affect the esophagus more than the stomach. Patients with cancer developing in a herniated intrathoracic stomach sometimes have a long history of dyspepsia antedating the onset of the cancer (Case 2). Irritative gastritis has never been satisfactorily proved to be a precursory lesion for gastric cancer.

In conclusion, therefore, we must admit that there is insufficient valid evidence to consider dystopia or ectopia of the stomach as a precancerous state, nor is the hazard of cancer occurrence in the herniated stomach, a sufficient indication in itself to influence the surgeon's decision whether or not to repair the hernia.

Symptomatology and Diagnosis of Cancer in the Intrathoracic Stomach.—The resectability of gastric cancers occurring in intrathoracic segments is undeniably lower than obtains for the same disease in normally located stomachs. Indeed many of the reported cases are based on necropsy findings. The long antecedent histories of dysphagia, esophagitis, heartburn, etc., associated with the known presence of a hiatus hernia (nine years in Case 2) may lull patient and physician alike into a false sense of security. The transition in symptoms caused by the mechanical abnormality to those due to gastric cancer may be difficult to perceive. The intervention of serious hemorrhages as in one of

our patients (Case 2) may lead to earlier surgical treatment. Gastroscopy with the rigid or flexible instrument may be indeterminate because of the distorted relationships of the esophagus and stomach. Correct roentgenographic diagnosis of cancer superimposed on an intrathoracic gastric segment or stomach is often difficult to make, in fact many more cases are incorrrectly diagnosed as cancer when the defect is only a mechanical distortion of a herniated portion of the stomach.



A. *B.*

Fig. 1.—*A* (Case 1), Roentgenogram to show supradiaphragmatic defect in gastric cardia. Note congenitally short esophagus. *B* (Case 1), Postoperative roentgenogram to show intrathoracic esophagogastrostomy after subtotal esophagogastric resection.

Surgical Treatment.—The more recent acceptance of laparothoracotomy as a routine measure for cancers of the proximal stomach and lower esophagus has given these patients an opportunity for cure. More successful surgical resections will undoubtedly be reported in the future. In the second case report, the total gastrectomy performed within the chest was done with the greatest ease and speed in our experience. The ligaments of the stomach and their contained blood vessels were transected and ligated with consummate ease. The duodenal stump and severed esophagus were so naturally and closely approximated that an end-to-end anastomosis well within the chest was readily done. It was not necessary to free the peritoneum along the lateral duodenolumbar gutter (Kocher maneuver) to mobilize the duodenum as was done in the olden days when subdiaphragmatic or abdominal esophagoduodenostomies were in vogue as the second phase of the operation of total gastrectomy.

CASE REPORTS

CASE 1.—*Subtotal esophago-gastrectomy for cancer in a thoracic gastric cardia:* G. G., a white man, aged 54 years, applied for treatment on April 29, 1949. For one year he had observed increasing discomfort on swallowing solid foods. For two months he had consumed only liquids. He had recently experienced constant, dull pain in the left upper abdominal quadrant. He had previously been told that he had a peptic ulcer. Physical examination was not informative of the diagnosis.

A roentgenogram of the chest showed a density superimposed on the heart shadow. Barium swallowing and radiographic studies demonstrated a dilatation of the esophagus and a large polypoid filling defect obscuring the mucosal pattern of a dystopic proximal segment of stomach within the chest. Esophagoscopy was performed and a biopsy obtained at a distance of 40 cm. from the incisor teeth; the microscopic diagnosis was adenocarcinoma.

Fig. 2.—(Case 2), Roentgenogram to show intrathoracic stomach with filling defect in gastric silhouette to correspond with site of carcinoma.

A thoracolaparotomy was done on May 31, 1949. The stomach was found to be projected high within the thoracic cage. A large tumor occupied the entire gastric cardia. The brachyesophagus ended only 4 cm. below the aortic arch. Moreover, large firm lymph nodes were found throughout the omentum and along the lesser gastric curvature. The stomach was transected at the lower fifth, and the distal gastric stump was anastomosed to the esophagus immediately below the aortic arch.

The microscopic analysis was: adenocarcinoma, grade II, with extension to the peritoneum and metastases to multiple lymph nodes along the lesser curvature.

Convalescence was normal, and he was discharged from the hospital on the twenty-third postoperative day. He achieved a good appetite and was able to ingest a high-protein, high-caloric, normal diet. On March 15, 1950, his liver was found to be massive, hard, and nodular. He died on April 11, 1950, one year following the gastrectomy and intrathoracic anastomosis.

The final diagnosis was adenocarcinoma occurring in an intrathoracic cardiac segment of the stomach associated with a congenitally short esophagus.

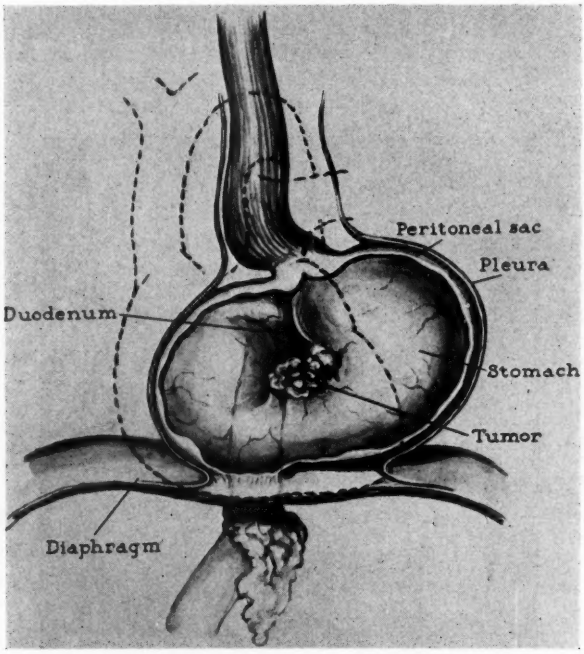


Fig. 3.—(Case 2). Diagram to show the relations of the cancer-bearing intrathoracic stomach. Note the proximity of duodenal bulb to the distal esophagus and the double investiture by peritoneal and pleural sacs.

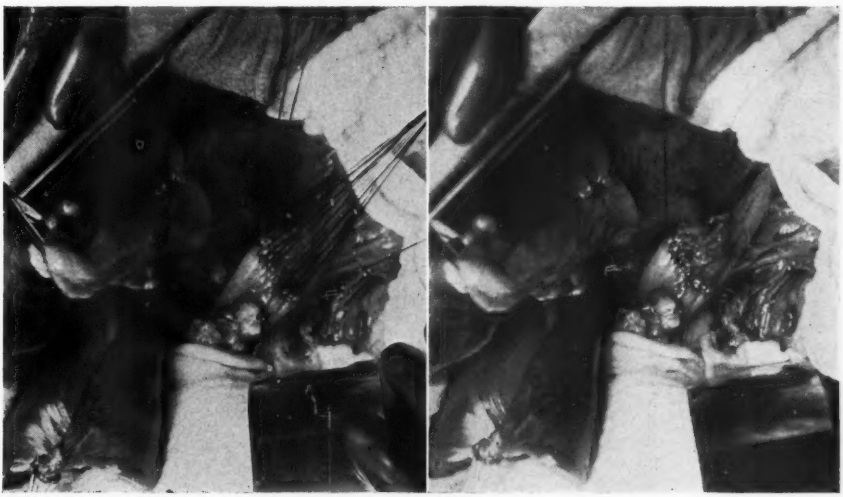
CASE 2.—*Total gastrectomy for cancer occurring in an intrathoracic stomach: intrathoracic esophago-duodenostomy:* M. G., a white man, aged 63 years, applied for treatment on April 6, 1950. His chief complaints were belching, eructation of liquids, postprandial pain, weakness, and loss of weight (40 pounds) of three months' duration. Another physician had treated him for anemia. On several occasions he had hemorrhages (hematemesis and melena), and had received six blood transfusions.

In his past experience he had occasional indigestion for many years: nine years previously roentgenographic studies were made following a barium swallowing, at which time the patient had been informed that his entire stomach was within his chest.

On physical examination, the patient appeared very anemic and cachectic. No other external evidence of disease was seen, and there were no palpable masses. Roentgenographic studies at this time revealed the stomach to be situated within the left hemithorax. There was a marked irregularity of the gastric silhouette, strongly suggesting the presence of a

carcinoma. An esophagoscopy was done, and a granular lesion visualized which was interpreted as carcinoma. A biopsy was performed which was not confirmatory of the clinical and radiographic opinion.

On April 14, 1950, a laparothoracotomy was done. From the abdominal aspect the stomach was absent, being retracted into the chest, with the greatly elongated duodenum extending into the diaphragmatic hiatus. The intrathoracic stomach was covered by a two-layered membrane, presumably peritoneum and mediastinal pleura, between which was a moderate serous transudate. A bulky tumor occupied the middle third of the stomach, and was situated chiefly on the lesser curvature. The tumor measured 6 cm. in diameter and invaded all coats of the stomach wall. The great omentum which was also within the chest contained numerous lymph nodes measuring 0.5 to 2.0 cm. in diameter.



A. *B.*

Fig. 4.—*A* (Case 2), Visceral view through laparothoracotomy incision after total gastrectomy. Photograph illustrates stage in esophagoduodenal anastomosis. *B* (Case 2), Completion of intrathoracic esophagoduodenostomy. The liver, lungs, spleen and pericardial sac have been retracted to afford a better view.

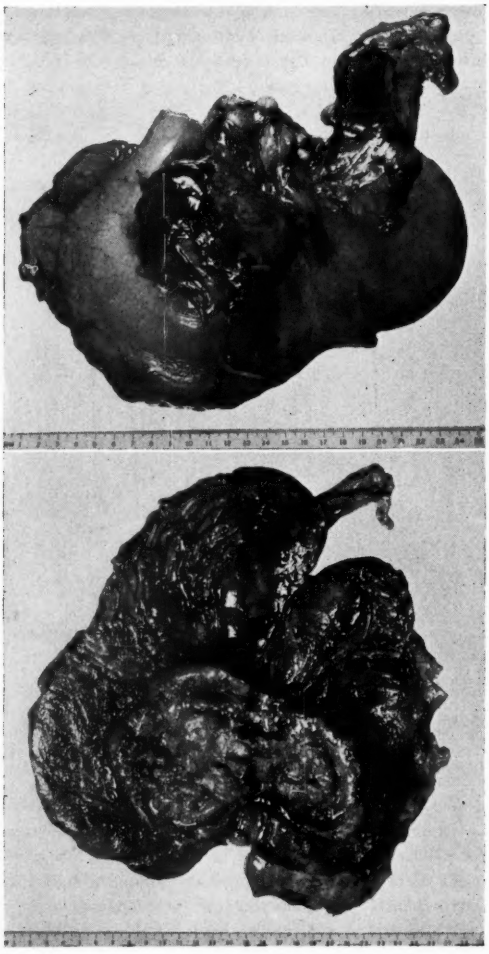
A total gastrectomy was done, the operation being consummated with extraordinary ease, because of the attenuation of the gastric ligaments and the unusual mobility of the stomach. At the completion of the operation, it was observed that the esophageal stoma and the duodenal stoma were conveniently adjacent within the midthorax, therefore it was logical and technically feasible to construct an esophagoduodenal anastomosis without tension. Two rows of interrupted silk sutures were employed in the anastomosis.

The patient did well postoperatively; he was ambulatory on the third postoperative day, the drainage tube was withdrawn on the seventh day, and he was discharged from the hospital on the twelfth postoperative day. He enjoyed a relatively soft diet with five small meals daily. His weight gradually increased. He resumed his work as a cutter in a clothing establishment. His only complaint has been an occasional regurgitation of bile.

Pathology Report: The surgical specimen showed a large tumor mass to be situated on the lesser curvature with serosal nodulations. On opening the specimen, a large ulcerating neoplasm, 15 cm. in diameter, was seen to straddle the lesser curvature and extend onto the anterior and posterior walls. The tumor extended to a point two centimeters proximal to

the pyloric ring. Microscopic study showed diffuse invasive replacement of the gastric wall by adenocarcinoma. The cells were of the signet-ring type. None of the perigastric lymph nodes contained metastatic cancer.

A.



B.

Fig. 5.—*A* (Case 2), Gross surgical specimen showing limits of duodenal and esophageal resection. *B* (Case 2), Ulcerating fungating saddle carcinoma developing on lesser curvature.

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SURGICAL TREATMENT OF POST-THORACOPLASTY PAINFUL BACK

LAWRENCE M. SHEFTS, M.D.*
SAN ANTONIO, TEXAS

APPROXIMATELY two and one-half years ago failure to relieve a patient of post-thoracoplasty pain by resection of the inferior angle and part of the body of the scapula resulted in a careful re-examination and evaluation of the *location* of the pain and of the *type of motion* that would increase it. It was found that the cause of the pain was the impingement of the scapula upon the vertebral column. Occasionally in any large series of thoracoplasties, there are some patients who, in spite of adequate physiotherapy, training in muscle education, and proper posture, complain of almost constant pain in their backs. Some with limited thoracoplasties are found to have as the cause of discomfort or pain the familiar condition of the inferior angle of the scapula impinging upon or snapping over the last remaining rib. This report does *not* concern itself with this group, for when careful examination reveals this condition to be present, resection of the required amount of the body of the scapula and/or resection of a portion of the next remaining rib usually suffice to relieve the symptoms. Surgeons are sufficiently aware of this anatomic situation to include frequently partial resection of the scapula as part of many limited thoracoplasties.

There are, however, patients whose cause of pain has no relation to this type of condition. This is quite evident, for there are patients whose pain persists who have previously had a resection of the inferior angle of the scapula, as in the case to be presented. Careful examination will reveal that the cause of their discomfort is the approximation or overriding of the vertebral border of the scapula to or onto the vertebral column. They have a constant dull ache in their backs or are aware of a sense of discomfort at all times, and this becomes pain whenever they "brace up" in an attempt to improve their posture or whenever they reach backward in such a manner as to push their scapula backward. All the patients complaining of this pain clearly list inability to rest or sleep on the side of the thoracoplasty. It is important in examining the patient to find out whether the pain radiates in such a fashion that one might feel that the intercostal nerves are involved. These patients do not have the deep intercostal nerve pain, but state their pain is in the paravertebral area and does not radiate.

Careful examination of these patients reveals how readily the malposition of the scapula occurs. When the patient braces, pulling the shoulder backward, one can see and feel the approximation or overriding. The jamming of the scapula against the vertebral column may be of sufficient tightness almost to hold in situ a sheet of paper.

*Civilian Thoracic Surgery Consultant to the Veterans Administration Hospital, Kerrville, Texas, Brooke Army Hospital, Fort Sam Houston, Texas, and the United States Air Force Hospital, Randolph Air Force Base, Texas.

Received for publication Nov. 28, 1951.

Following the thoracoplasty there is always a relative atrophy of the musculature of the operated side (Fig. 1). There is an atrophy of the trapezius and rhomboid muscles on this side. There is also an atrophy of some of the flat and long muscles of the back, as can be seen in the cross section (Fig. 1).

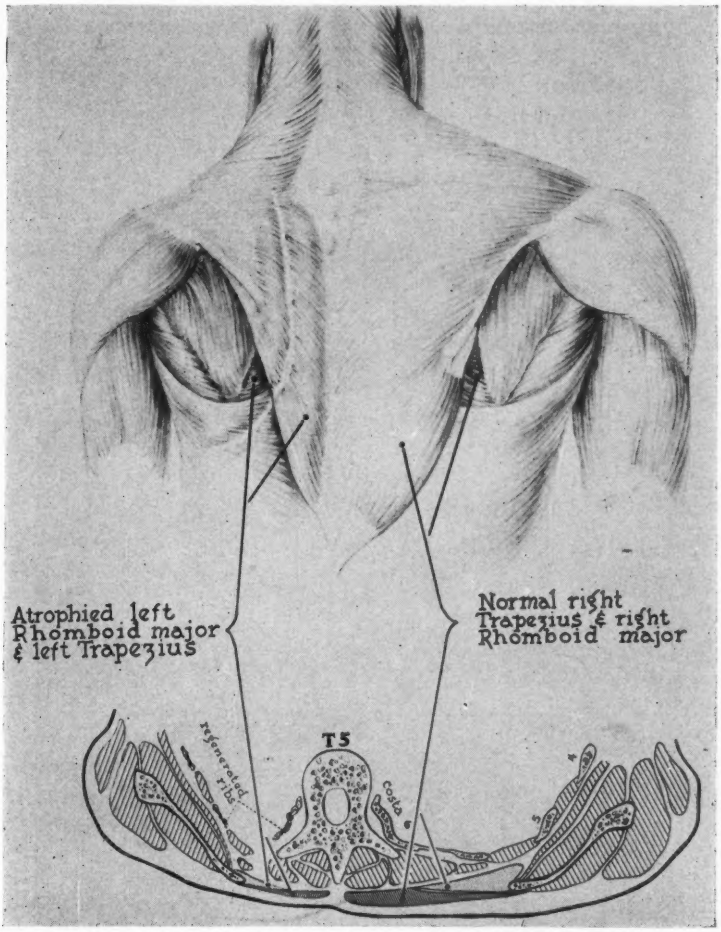


Fig. 1.—The atrophy following a thoracoplasty is depicted above. In the cross section the transverse processes are shown in order to maintain the relationships.

The following may be involved all or in part: Longissimus dorsi and cervicis, spinalis and semispinalis dorsi, and multifidus. These are the muscles that pad in the concavity between the dorsal spines and the transverse processes. This atrophy results from the stretching of this muscle group due to the scoliosis following a modern radical thoracoplasty. The unopposed action of the ligaments and muscles on the contralateral side acts as a bowstring. This scoliosis

is, of course, less marked when the transverse processes are not disturbed, but the condition being described can occur following a thoracoplasty wherein the transverse processes are not disturbed, as in one of the cases. The vertebral column loses its protective padding by such atrophy. This atrophy can be

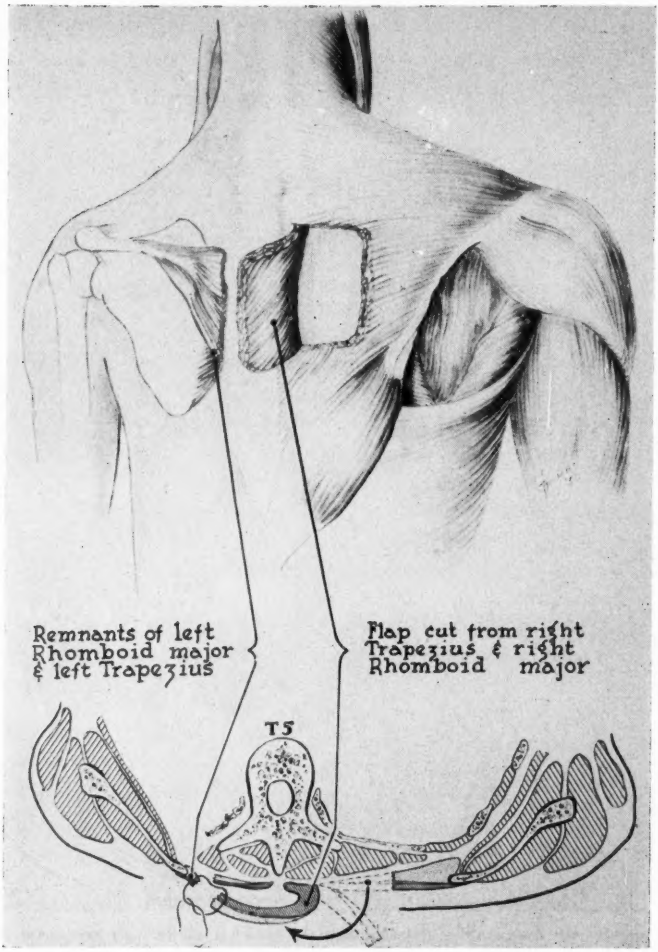


Fig. 2.—Procedure I. The muscle flap from the right is swung over to the opposite scapula.

noticed if one observes this region in the process of exposure for resections under previous thoracoplasties. It permits the scapula in the backward movement of the shoulder to ride against or even onto the vertebral column. There is also in any given patient the possibility of replacement of the trapezius and rhomboid muscles by a thin layer of scar tissue. This can be expected in those pa-

tients in whom there occurs the following during the thoracoplasty stages: inadequate primary closure of the muscle layers, infection with greater or less disruption of the wound, and excessive fluid formation that is not immediately recognized and removed. The latter can disrupt muscle layers and be contained

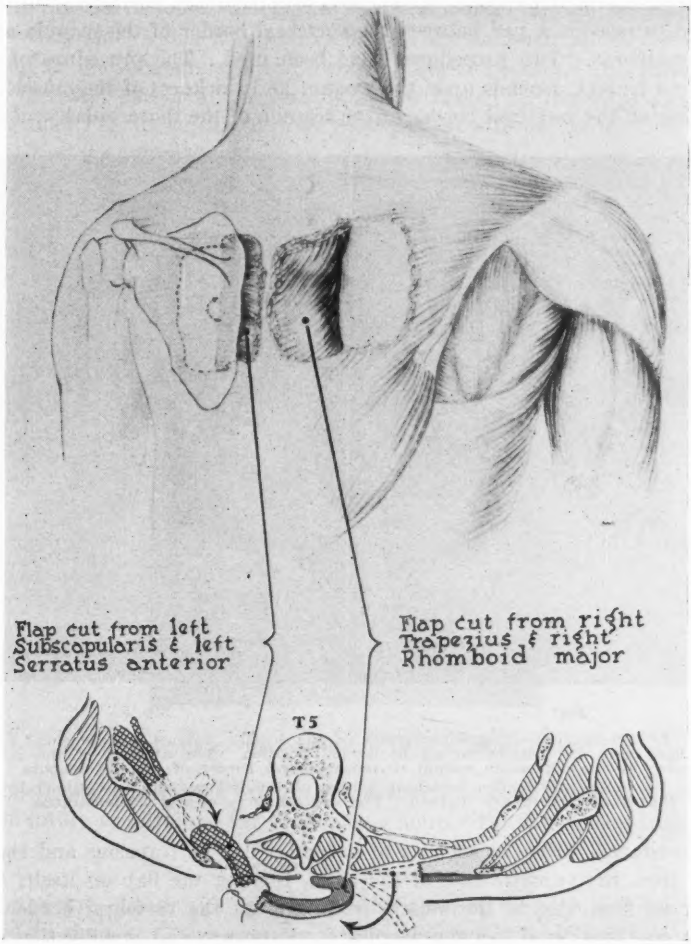


Fig. 3.—Procedure II. The muscle flap from the right and a flap from the scapula are obtained as shown above.

by the skin closure. In the eight patients who comprise this series, attempts were made to determine which, if any, of these conditions were present at the time of thoracoplasty. As the thoracoplasties in seven of the patients were not done by the author, it was difficult to elicit the above complications. However,

in at least one of the seven, infection may well have been a factor. The eighth case was due to neglect in aspiration of a collection of subscapular fluid, wherein the muscle was disrupted and the fluid was contained by the skin closure.

OPERATIVE PROCEDURES

The bases of the treatment of this condition are operative procedures designed to provide a pad between the vertebral border of the scapula and the dorsal vertebrae. Two procedures have been used. The procedure of choice in a given patient depends upon the amount and thickness of the muscle found remaining on the vertebral border of the scapula of the thoracoplasty side.

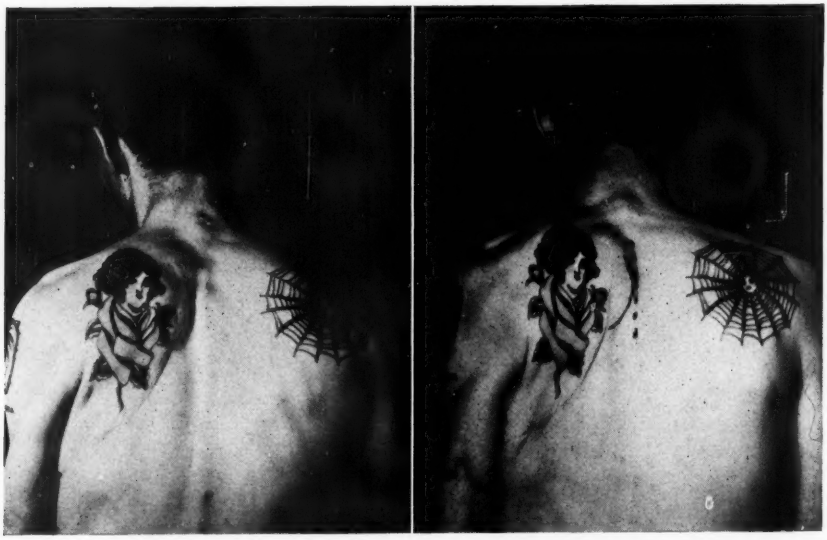


Fig. 4. Fig. 5.

Fig. 4.—Preoperative—The impingement of the scapula against the vertebral column is shown above with the patient sitting in normal position. The atrophy of the muscles is demonstrated by the depression medial to the vertebral border of the left scapula.

Fig. 5.—Preoperative—The vertebral border of the left scapula is outlined by a solid line and the dorsal spines are marked. The overriding is clearly demonstrated.

Procedure I (Fig. 2) consists of raising a flap of trapezius and rhomboid muscle from the *opposite* side of the chest, turning the flap on itself, and attaching its free edge to the muscle remaining on the vertebral border of the scapula on the side of the thoracoplasty. Exposure and mobilization are obtained as follows: the greater part of the scar of the previous thoracoplasty operation is removed. The skin and subcutaneous tissue nearest the vertebral column is undercut and dissected *across* the dorsal spines over to the edge of the vertebral border of the opposite scapula. A muscle flap of trapezius and rhomboid is cut from this side, based on their attachments to the vertebral column. This flap is then turned on itself across the dorsal spine (as seen in the cross section, Fig. 2) and attached to the muscle remnants along the

vertebral border of the scapula. In preparing the muscle along the vertebral border of the scapula of the thoracoplasty side, the scar tissue replacement can be incised, and some fairly good muscle fibers may be found and thus utilized.

Procedure II (Fig. 3): Exposure is obtained and the muscle flap raised from the opposite side as in Procedure I. When, after careful dissection, insufficient muscle is found along the vertebral border of the scapula of the thoracoplasty side, a flap may be raised from the undersurface of the scapula, consisting of the subscapularis and serratus anterior muscles. This flap is based on the vertebral border of the scapula and is turned on itself (as seen in the cross section, Fig. 3) so that its free edge may be attached to the free edge of the flap from the opposite side.

Fig. 6.—Preoperative—The overriding of the left scapula upon the vertebral column is in this case almost sufficient to hold a piece of paper in situ.

In both procedures, the regions of the source of each flap and its eventual point of suture are drained for twenty-four hours with flat rubber drains.

POSTOPERATIVE CARE

A pressure dressing is applied to the area of surgery and the arm is strapped to the side. The shoulder is partially pulled backward and held by adhesive running from the shoulder diagonally down and across the operative area onto the opposite chest. The skin sutures and pressure dressing are removed on the sixth day, the arm remaining fastened to the patient's side for ten days. Physiotherapy is not started until the third or fourth week.

A typical example is as follows: A. L. A., a white man, aged 48 years, with pulmonary tuberculosis diagnosed in May, 1945, as moderately advanced and active. Initial left pneumothorax was unsuccessful in April, 1949, and a left six-rib thoracoplasty done

elsewhere was completed in July, 1949. Roentgenograms revealed excellent collapse with adequate removal of each rib and transverse process. The inferior angle of the scapula was resected as part of the second stage. Sputum and gastric cultures were negative for tuberculosis in July, 1950. Starting approximately one month after completion of the operation, the patient had discomfort on attempting to pull his shoulder back. In three more months this progressed to actual pain on attempting to reach behind him with his left hand. He had never been able to lie or sleep on his left side since the thoracoplasty. Fig. 4, 5, and 6 demonstrate the preoperative findings. Fig. 4 shows the impingement of the scapula onto the vertebral column with the patient sitting in normal position. The atrophy of the muscles is demonstrated by the depression medial to the vertebral border of the left scapula. In Fig. 5 the overriding is clearly demonstrated, as the dorsal spines

Fig. 7.

Fig. 8.

Fig. 7.—Postoperative—Patient with arms pulled forward. The fullness of the left paravertebral area can be observed, as well as a slight swelling over the dorsal spines at the point of crossing of the muscle flap from the right.

Fig. 8.—Postoperative—This indicates the relative positions of the medial border of the scapula and the dorsal spines.

and scapula are outlined. Fig. 6 reveals that the overriding of the left scapula upon the vertebral column is in this case sufficient to hold a piece of paper in situ. Figs. 7, 8, 9, and 10 demonstrate the result approximately one and one-half months after surgical Procedure II was carried out. Fig. 7 shows the result with the patient's arms pulled forward. The fullness of the left paravertebral area can be observed, as well as a slight swelling over the dorsal spines at the point of crossing of the muscle flap from the right. Fig. 8 indicates the relative positions of the medial border of the scapula and the dorsal spines with the patient sitting in normal position. Fig. 9 shows the bulge of the interposed muscle flaps when the shoulder is pulled backward. Fig. 10 demonstrates the relative positions of the vertebral border of the scapula and the dorsal spines when the shoulder is pulled backward.

RESULTS

Eight patients have been operated upon by Procedures I and II in the last two and one-half years, and all were relieved of their symptoms. The first one

was operated on in May, 1949, and the last in March, 1951. There has been no atrophy of the muscle flaps. There has been no interference in range of motion not previously present. Procedure I was done in five patients, and Procedure II was necessary in the remaining three. Three patients originally had a partial scapulectomy. Two of these scapulectomies were done as part of a second stage thoracoplasty, and one was done following the last stage of thoracoplasty. Five of the thoracoplasties were done in three stages, and three in two stages. The

Fig. 9.

Fig. 10.

Fig. 9.—Postoperative—This indicates the bulge of the interposed muscle flaps when the shoulder is pulled backward.

Fig. 10.—Postoperative—This demonstrates the relative positions of the vertebral border of the scapula and the dorsal spines when the shoulder is pulled backward.

most ribs removed in one case were nine, and the least were five. In all but one, the posterior rib segments and transverse processes were removed. The interval of time between the last stage of thoracoplasty and surgical Procedures I and II averaged fourteen-plus months—the longest was twenty-four months and the shortest eight months.

DISCUSSION

When one sees large groups of thoracoplasty patients, it becomes obvious that many of them have aches or pains of one sort or another with reference to their thoracoplasties. It is apparent that it requires careful, patient, and detailed examination in order to find out whether these symptoms are due to the more common cause of the impingement of the inferior angle of the scapula over remaining ribs, true intercostal nerve pain, or, less commonly, the anatomic condition described in this report. It is advised that each patient complaining of pain be carefully examined and, without asking leading questions, be per-

mitted to tell you where his pain is and what brings it about. It is felt that patients who could receive marked or complete relief by the procedures described herein are passed by with too casual an examination. This may be observed in the fact that in one of the patients, resection of a portion of the scapula was done to relieve his pain and it failed completely, there being no change in the patient's symptoms after the partial scapulectomy. When re-examined, the findings and history revealed the condition to be present as described herein, and one of the surgical procedures gave him complete relief. It is obvious that only inadequate examination and questioning resulted in some unnecessary surgery.

CONCLUSIONS

1. Attention is called to the post-thoracoplasty impingement or overriding of the scapula onto the vertebral column as the cause of pain.

2. Possible causes in development of this condition are listed.

3. Two operative procedures used in alleviation of this condition are described.

4. Results in eight cases are reported, and a case is presented demonstrating the pre- and postoperative condition.

LIMITED THORACOPLASTIES WITH EXTRAFASCIAL APICOLYSIS

WILLIAM R. SWEETMAN, M.D.
PORTLAND, ORE.

SINCE the advent of thoracoplasty in the treatment of pulmonary tuberculosis in 1888, modifications of the original procedure have been legion. In recent years, however, the "standard thoracoplasty" in the United States has been that advocated and popularized by Alexander and Churchill and their followers. Despite good general results reported in the literature, there have been from 15 to 25 per cent failures, the deformity has been considerable, and there has been immobilization of rather large portions of adjacent normal lung because of the extent of the rib resection. Little known and poorly understood in this country is Semb's apicolysis used in conjunction with a limited thoracoplasty.[1] The applicability and success of this method will be illustrated in the following series of consecutive thoracoplasties of five or less ribs performed in the Oslo Municipal Hospital and the Oslo Municipal Tuberculosis Sanatorium from 1942 to 1949.

There are 174 cases in all, five bilateral, with a total of 261 stages of operation. The operations were done according to the method of Semb,* many of them performed by him.

Since the development of this method in 1935, the operation has become more moderate and selective. Fewer and less extensive segments of ribs are resected without reducing the size of the apicolysis. Thus a seven-rib thoracoplasty has given way to a six-rib combined with partial scapulectomy, to a five-rib two-stage procedure, to a one-stage four-rib operation. The results have not suffered from this reduction in the extent of the rib resection.

Another modification has been the development of a method of maintaining the collapse after operation. In the early years up to 1944, only saline was placed in the apicolysis cavity. Then mineral oil filling was begun with noteworthy success in preventing re-expansion of the apex until the ribs had regenerated over the new apical level. In an effort toward further improvement, air filling† was instituted in 1947, introducing pressures up to 40 to 50 cm. of water. These fillings are done on the fourth, eighth, and twelfth postoperative

Received for publication Dec. 12, 1951.

*Through a paravertebral subscapular incision about one-third of the third rib, three-fourths of the second, and all of the first rib are resected dividing their intercostal bundles. The apex of the lung is freed in the extrafascial plane beginning in the sheath of the brachial plexus and extending down beyond the azygos vein on the right and the arch of the aorta on the left: anteriorly to the second rib and posteriorly to the sixth or seventh ribs. The space is half filled with saline before closure. At the second stage the space is reopened; about one-half to two-thirds of the fourth, one-third of the fifth, the remainder of the second and most of the residual third ribs are resected. The intercostal bundles are divided posteriorly and often sutured over the new apical level. Cancellous bone chips are also in recent years placed over the apex to supplement the regenerated ribs. The space is again half filled with saline followed by postoperative air filling (Fig. 1.).

†An ordinary pneumothorax needle is inserted at the upper end of the incision toward the nipple in order to enter the upper posterior part of the apicolysis space. When the manometer moves with respiration or coughing, the cavity has been reached. Air is then insufflated up to pressures between 20 to 30 c.c. of water. Later following the second stage of operation pressures can be effected up to 60 c.c.

days after the first stage of the operation, fourth, tenth postoperative days after the second stage, and weekly thereafter until new ribs are seen and the new thoracic roof is stable. The residual air is then gradually absorbed.

Of the 174 cases, 93 were five-rib, 66 were four-rib, and 15 were three-rib thoracoplasties. This final group was composed primarily of cases with postoperative complications or x-ray evidence of cavity closure. The over-all mortality was 3.5 per cent, and rate of cure 88.5 per cent (Table I).

Of the five-rib group eighty-two, or 88 per cent, of the ninety-three cases have no roentgenographic evidence of cavitation, as evidenced by planigrams, are repeatedly negative by culture, and are in full- or part-time work. The operative mortality in this group is 1.1 per cent, and there is a late mortality of 2.2 per cent. The residual cavity rate is 8.6 per cent.

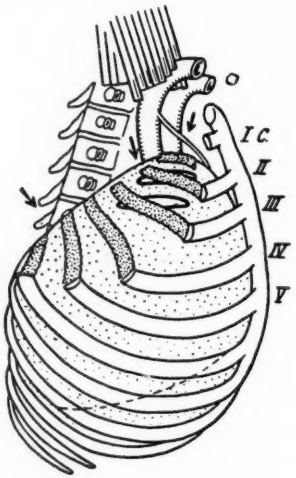


Fig. 1.—Diagrammatic representation of the extent of rib resection in a six-rib thoracoplasty.

TABLE I. COMBINED STATISTICS OF CONSECUTIVE CASES FROM 1942 TO 1949. SMALL THORACOPLASTIES

NO. RIBS	NO. PAT.	STAGES	NO. BILATERAL OP.	INFECTION	MORTALITY LESS THAN 2 MO.	LATER MORTALITY	FOLLOW UP 3 MO. TO 7 YR.	
							CAV.− TB.−	CAV.+ TB.+
3	15	15	−	2 13 per cent	1 6.6 per cent	3 20 per cent	10 66.6 per cent	1 6.6 per cent
4	66	74	2	1 1.5 per cent	1 1.5 per cent	1 1.5 per cent	62 94 per cent	2 3.3 per cent
5	93	172	3	5 5.4 per cent	1 1.1 per cent	2 2.2 per cent	82 88 per cent	8 8.6 per cent
Total	174	261	5	8	3	6	154	11
Per cent				2.2 per cent	1.7 per cent	3.5 per cent	88.5 per cent	6.3 per cent

Of the sixty-four four-rib cases, sixty-two, or 94 per cent, have no roentgenographic evidence of cavity, and are repeatedly negative on culture. The operative mortality and late mortality is 1.5 per cent. The residual cavity rate is 3.3 per cent.

The three-rib group of fifteen cases resulted in ten cures or 66.6 per cent. The operative mortality was 6.6 per cent, and late mortality 20 per cent. Residual cavity has been found in one, or 6.6 per cent.

The combined late mortality in the four- and five-rib thoracoplasties was 1.9 per cent.

The follow-up period is from under one year to seven years, with about half of the cases two or more years (Table II).

The cavities have been located predominantly above the level of the fifth rib posteriorly (Fig. 2). They can be classified in three groups: Group I, 0 to 2.5 cm.; Group II, 2.5 to 4 cm.; and Group III, 4 to 5 cm. The greatest number were in the first group (Table III).

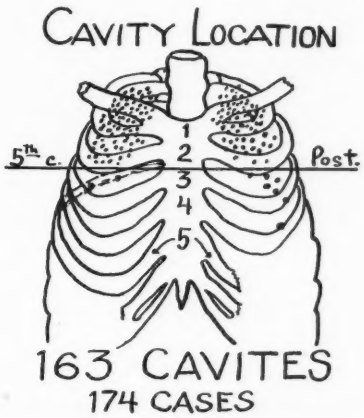


Fig. 2.—Cavity location

TABLE II. OBSERVATION TIME

RIBS	UNDER & 1 YR.	2 YR.	3 YR.	4 YR.	5 YR.	6 YR.	7 YR.	TOTAL
3	6	3	5	–	1	–	–	15
4	41	9	5	7	2	2	–	66
5	44	18	12	9	7	2	1	93
Total	91	30	22	16	10	4	1	174

TABLE III. CAVITY SIZE ACCORDING TO EXTENT OF RIB RESECTION

Ribs	I 2.5 CM.	II 2.5-4 CM.	III 4-5 CM.	SINGLE	MULT.	TOTAL
3	15	–	–	14	1	15
4	58	3	–	54	7	61
5	69	15	3	67	20	87
Total	142	18	3	135	28	163

When the cavity size is plotted against the number of ribs resected, it is found that of 142 cases from Group I (0 to 2.5), 129 or 90.8 per cent were treated successfully, one died in the postoperative period, and seven, or 4.9 per cent, were left with residual cavities. This contrasts sharply with the next group (2.5 to 4) where of the eighteen cases, although there were no operative deaths, only thirteen or 72.2 per cent were cured, and four or 22.2 per cent had residual cavities. This suggests that cavity size is an important factor in determining the chance of success with a small thoracoplasty (Table IV).

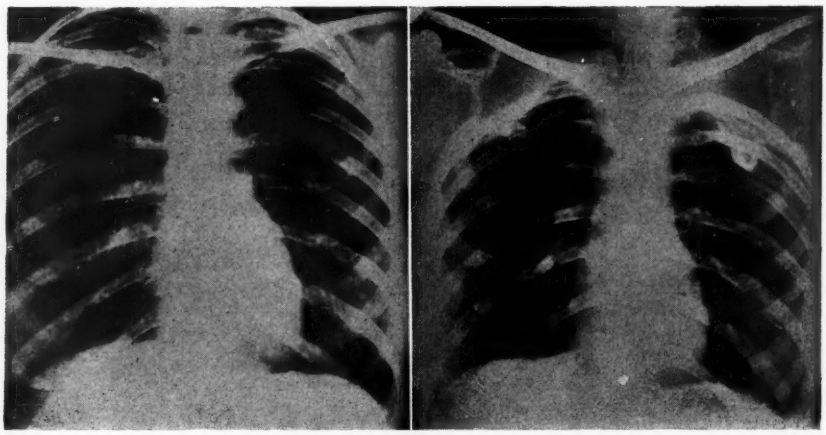


Fig. 3. Fig. 4.

Fig. 3.—(Case 1.) Preoperative roentgenogram.
Fig. 4.—(Case 1.) Eight months after the four-rib thoracoplasty on the left and four months after that on the right.

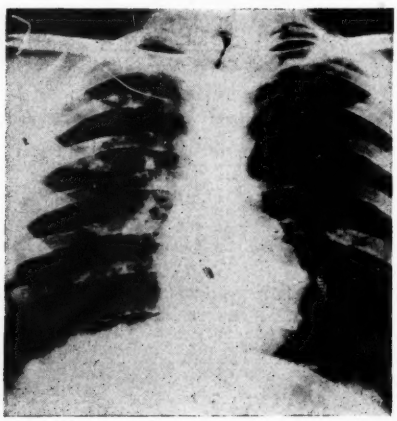


Fig. 5.—(Case 2.) Preoperative roentgenogram.

As an incidental finding it was noted that twenty-eight patients, or 17 per cent, had been treated by artificial pneumothorax, an average of 5.5 years with reformation of cavities after re-expansion (Table V).

COMMENT

This study has been undertaken in an attempt to evaluate the effectivity and validity of a limited thoracoplasty done in conjunction with a large extrafascial apicolysis in the treatment of apical tuberculosis with cavitation. These

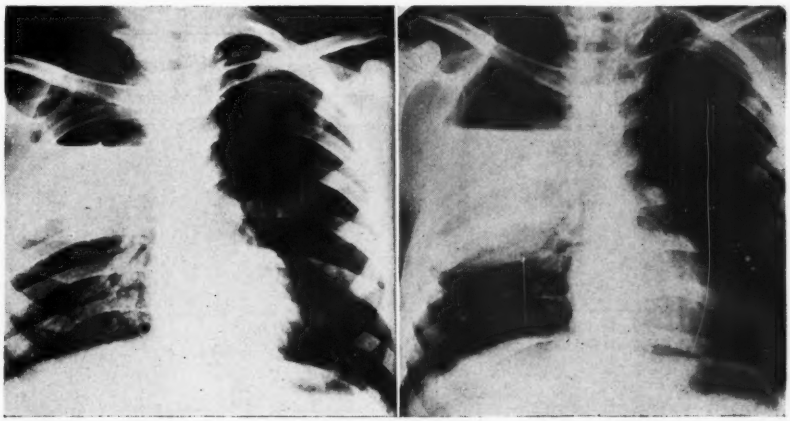


Fig. 6. Fig. 7.

Fig. 6.—Case 2 after first stage and one air filling.
Fig. 7.—Case 2 after second stage and additional filling.

Fig. 8.—Case 2 after second stage, lateral view.

TABLE IV. EARLY AND LATE RESULTS CORRELATED WITH CAVITY SIZE 3, 4, AND 5 RIB THORACOPLASTIES

CAVITY SIZE	NO.	INF.	MORT. LESS THAN 2 MO.	MORT. LATER	CAV. − TB. −	CAV. + TB. +
I 0-2.5 cm.	142	8	1	5	129 90.8 per cent	7 4.9 per cent
II 2.5-4 cm.	18	-	-	1	13 72.2 per cent	4 22.2 per cent
III 4-5 cm.	3	-	-	-	3 100 per cent	-
Total	163	8	1	6	145 88.9 per cent	11 7.6 per cent

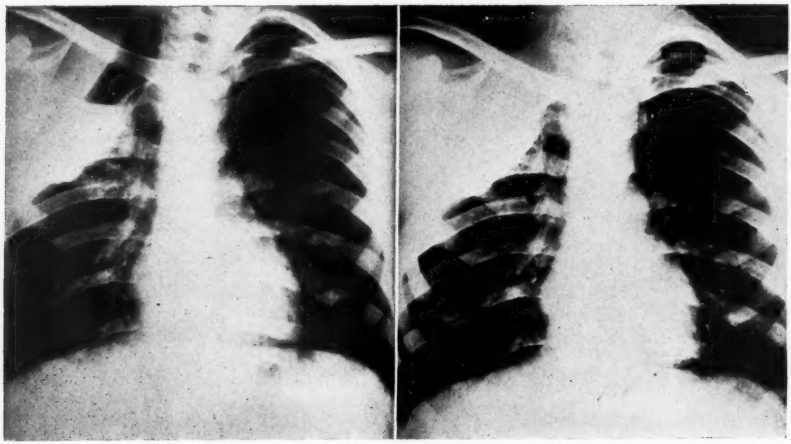


Fig. 9. Fig. 10.

Fig. 9.—Case 2 after 3 months; air filling discontinued.
Fig. 10.—Case 2, four months after air filling was discontinued.

TABLE V. NUMBER OF YEARS BETWEEN THE INSTITUTION OF PNEUMOTHORAX AND OPERATION. RESIDUAL CAVITY AFTER A-P.

5 ribs	19	Av. Years between
4 ribs	8	A-P and operation
3 ribs	1	5.5
Total	28—17 per cent	

results illustrate what can be achieved with a minimum of outward, and more important, inward deformity. The diseased portion of the lung with its cavity or cavities is permanently collapsed, allowing a minimal loss of function of the remaining unaffected lung. This has been achieved with a low mortality both postoperative and late. Planigraphic studies have been carried out in the majority of cases both before and after operation (Figs. 11 and 12). Recently planigrams have been taken routinely pre- and postoperatively to study the relationship of the drainage bronchus to the ultimate result. In several of the cases of residual cavity open drainage bronchi can be demonstrated.

To achieve success with such a limited rib resection, especially in the four-rib one-stage operations, an extensive and exact extrafascial apicolysis is of the utmost importance. Of almost equal importance is the vigilant filling, preferably with air, of the apicolysis space until regenerated ribs are fully formed.

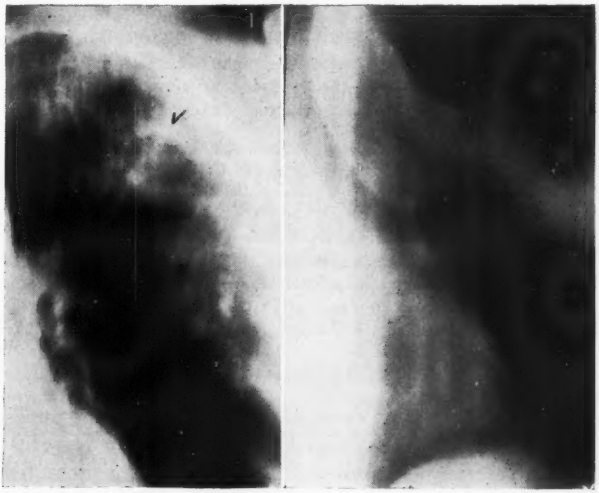


Fig. 11.—Planigrams before and ten days after a five-rib thoracoplasty with extrafascial apicolysis.

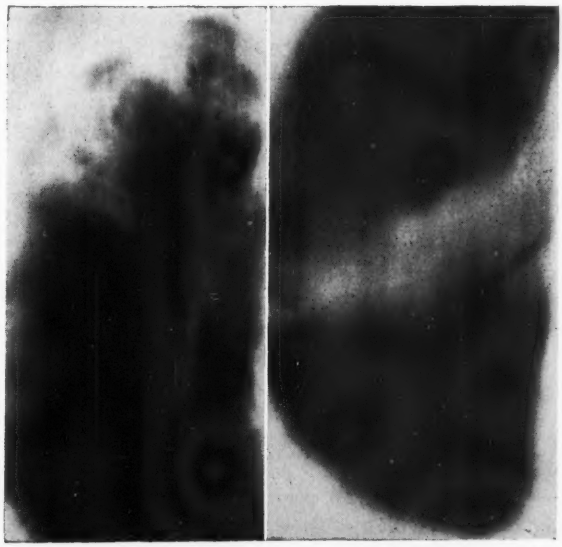


Fig. 12.—Planigrams before and ten days after a five-rib thoracoplasty with extrafascial apicolysis.

CASE REPORTS

CASE 1.—This 42-year-old white woman developed pleurisy in 1926. She was treated by a right pneumothorax from 1936 to 1940. In December, 1946, she became weak, began to cough, and a chest roentgenogram revealed bilateral apical infiltration with cavitation (Fig. 3). Pneumothorax was unsuccessful. Sputum was positive on direct smear, vital capacity was 2,500 c.c., and there was excellent diaphragm movement on both sides. Because of her good general condition and the small cavities located well up in the apices, it was decided to perform bilateral four-rib thoracoplasties with extrafascial apicolysis. The left side was done first. The right side was done after a four-month interval (Fig. 4). Four months later the sputum was negative on smear but positive a single instance in a culture from gastric contents. Planigrams were negative for residual cavity.

CASE 2.—This 18-year-old man developed tuberculosis in 1947. He was admitted to Oslo Municipal Hospital four months later with bilateral infiltration and right upper lobe cavitation. The sputum was strongly positive on direct smear. Pneumothorax was unsuccessful on the left and contraselective. His vital capacity was 3,600 c.c., and diaphragmatic movement was excellent. The daily sputum varied from 10 to 30 c.c. A five-rib thoracoplasty with extrafascial apicolysis was therefore performed in two stages in conjunction with air filling. Two years after the final stage he was well and working with negative sputum cultures and no planigraphic evidence of residual cavitation (Figs. 5 to 10).

SUMMARY

One hundred seventy-four cases of tuberculosis of the lungs treated by thoracoplasty with extrafascial apicolysis involving five or less ribs with a total of 261 stages of operation are reviewed. The results are presented and briefly discussed.

REFERENCE

1. Semb, Carl: Thoracoplasty with Extrafascial Apicolysis, Acta chir. Scandinav. **76**: 1-85, 1935. Supp. 37 (art. 2).

PULMONARY RESECTION FOR TUBERCULOSIS

EUGENE B. SIVE, M.D., EMIL BOGEN, M.D., AND FRANK S. DOLLEY, M.D.
OLIVE VIEW, CALIF.

PULMONARY resections for tuberculosis have been reported over a period of half a century, but it is only during the past decade that resection has become recognized as an approved therapeutic measure, and that any large series of cases has been reported. Sporadic instances of resections were performed on Olive View patients before the introduction of streptomycin, and in a few instances the results were gratifying, but the incidence of bronchopleural fistula and empyema, and the high operative mortality in the cases operated by the old tourniquet method and without the aid of streptomycin, resulted in the reservation of this procedure for cases in which nothing else could be done. During the past four years, however, resection has been increasing in popularity here, as elsewhere, and is now recognized as an established procedure.

This paper presents a critical analysis of all cases of pulmonary resection for tuberculosis performed by the individual ligation technique at Olive View Sanatorium through Dec. 31, 1950. The series comprises eighty-four consecutive cases of pulmonary resection, of which one operation was performed in 1947, four in 1948, thirty-six in 1949, and forty-three in 1950. Complete follow-up data were obtained as of Nov. 1, 1951, in all but two cases. The last follow-up in one of the cases was one year after the surgery in June, 1950. The other follow-up was made in August, 1950, four months after surgery. In these two cases we are using the information as of that date.

In order to evaluate the resections, the results are divided into five categories: good, satisfactory, fair, poor, and deaths. The first three groups are further divided into working and not working classifications. Criteria used for establishing the groups are as follows:

Good: Cases that have done well and have remained well. All sputum concentrates, cultures, and gastric cultures have been negative since surgery. There were no spreads, no postoperative complications, no bronchopleural fistulas except in one case in which the bronchial stump leaked immediately and was repaired within twenty-four hours. This case is being included since it was obviously a surgical defect and had no connection with the result, so far as tuberculosis is concerned. In this group there are twenty-nine cases; thirteen of whom are now working, five full time.

Satisfactory: In this group are placed the cases who are as well now as are the cases in the *good* group, but have had, since surgery, one or more of the following: (a) positive sputum or gastric culture, now negative, (b) a spread that has cleared, (c) bronchopleural fistula, now closed, and (d) other postoperative complications from which there has been complete recovery. In this group are twenty-five cases, seven of whom are now working, one full time.

Received for publication Dec. 14, 1951.

TABLE I. RESULTS OF PULMONARY RESECTION FOR TUBERCULOSIS

	GOOD WORKING		SATISFACTORY WORKING		FAIR WORKING		POOR	DIED	TOTALS
	YES	NO	YES	NO	YES	NO			
Sex and Age, Males 10-29	4	2	0	2	0	2	1	1	12
30-39	2	0	4	3	1	0	0	4	14
40-49	3	4	1	1	0	1	1	0	11
50 and over	0	1	0	0	0	1	1	1	4
Totals	9	7	5	6	1	4	3	6	41
Females 10-29	2	1	2	6	1	2	2	1	17
30-39	2	3	0	1	1	3	3	1	14
40-49	0	4	0	3	0	1	0	0	8
50 and over	0	1	0	2	0	0	0	1	4
Totals	4	9	2	12	2	6	5	3	43
Race White	3	12	3	5	2	3	1	3	32
Mexican	8	4	2	8	1	5	4	3	35
Negro	1	0	1	3	0	1	1	2	9
Other	1	0	1	2	0	1	2	1	8
Totals	13	16	7	18	3	10	8	9	84
Patients working, 1-4 hr. Men	3		3		1				7
Women	4		2		0				6
5-7 hr. Men	1		1		0				2
Women	0		0		2				2
8-9 hr. Men	5		1		0				6
Women	0		0		0				0
Totals	13	0	7	0	3	0	0	0	23
Disease: Unilateral	0	2	1	1	0	0	0	0	4
Unilateral with cavity	1	2	0	2	0	1	0	0	6
Bilateral	8	6	2	5	1	3	3	5	33
Bilateral with unilateral cavity	4	6	4	10	2	6	5	4	41
Totals	13	16	7	18	3	10	8	9	84
Cavity size: under 2 cm.	5	5	1	5	0	3	3	0	22
2 cm. and over	0	2	4	6	2	4	1	4	23
Totals	5	7	5	11	2	7	4	4	45
Cavity character: Slit	2	2	1	0	0	0	0	0	5
Bronchiectatic	1	2	0	2	0	1	1	0	7
Irregular	0	1	1	2	1	3	0	1	9
Round	0	1	2	2	0	1	1	1	8
Totals	3	6	4	6	1	5	2	2	29
Cavity location: Upper lobe	4	6	3	11	1	4	4	4	37
Lower lobe	1	1	2	1	1	3	0	0	9
Totals	5	7	5	12	2	7	4	4	46
Duration of disease: 0-1 yr.	1	3	1	1	0	0	2	1	9
2-4 yr.	3	1	2	7	0	3	2	2	20
5-9 yr.	5	9	2	8	2	4	3	2	35
10 and over	2	3	1	1	1	1	0	2	11
Totals	11	16	6	17	3	8	7	7	75
Preoperative sputum, Positive Conc.	2	6	3	8	2	5	3	3	32
Intermittent Pos. Conc.	1	4	1	3	0	1	0	1	11
Occasional Pos. Conc.	3	0	1	0	0	0	1	1	6
Neg. Conc.—Pos. Culture	2	1	1	4	0	3	3	3	17
Neg. Conc. Inter. Pos. Culture	3	2	1	2	0	1	1	1	11
Neg. Conc. Occas. Pos. Culture	0	2	0	1	1	0	0	0	4
Neg. on Conc., Cult. and Gastric	2	1	0	0	0	0	0	0	3
Totals	13	16	7	18	3	10	8	9	84
Previous thoracoplasty: 3 ribs	0	0	0	1	0	0	0	0	1
5 ribs	1	4	2	5	1	1	2	0	16
6 ribs	0	3	1	1	1	0	2	1	9
7 ribs	5	5	1	6	1	3	4	3	28
8 ribs	2	0	0	2	0	2	0	2	8
9 ribs	1	1	1	1	0	1	0	1	6
Totals	9	13	5	16	3	7	8	7	68

TABLE I.—CONT'D

	GOOD WORKING		SATISFACTORY WORKING		FAIR WORKING				
	YES	NO	YES	NO	YES	NO	POOR	DIED	TOTALS
Types of resection: primary	4	3	2	2	0	3	0	2	16
after homolateral thoracoplasty	4	11	4	14	3	6	6	4	52
after bilateral thoracoplasty	0	0	0	1	0	0	0	0	1
after contralateral extrapleural pneumothorax and homolateral thoracoplasty	0	0	0	0	0	0	0	1	1
after revision thoracoplasty	3	0	0	1	0	1	1	1	7
after lucite pack and thoracoplasty	2	2	1	0	0	0	1	1	7
Totals	13	16	7	18	3	10	8	9	84
Streptomycin 5-39 grams	9	7	3	13	2	5	2	2	43
40 or more	3	9	4	5	1	5	5	6	38
No streptomycin	1	0	0	0	0	0	1	1	3
Totals	13	16	7	18	3	10	8	9	84
Preoperative bronchoscopy									
No discharge	4	4	0	6	1	3	2	3	23
Secretions, homolateral	3	6	1	7	0	2	2	2	23
Secretions, contralateral side	0	1	0	1	0	0	0	0	22
Secretions, both sides	0	1	0	0	0	0	0	0	1
Stenosis homolateral	1	5	1	4	0	4	2	1	18
Totals	8	17	2	18	1	9	6	6	67
Streptomycin resistant	0	3	0	3	0	1	5	4	16
Not streptomycin resistant	13	13	7	15	3	8	4	5	68
Totals	13	16	7	18	3	9	9	9	84
Previous tracheobronchial disease	4	6	2	2	0	3	6	0	23
No previous tracheobronchial disease	9	10	5	16	3	6	3	9	61
Totals	13	16	7	18	3	9	9	9	84
Operation:									
Pneumonectomy, left	4	6	2	6	0	3	3	4	28
Pneumonectomy, right	3	7	4	3	1	4	2	4	28
Lobectomy, left upper	1	2	0	5	0	1	0	1	10
Lobectomy, right upper	3	0	0	3	0	1	2	0	9
Lobectomy, left lower & lingula	1	0	0	0	0	0	0	0	1
Lobectomy, left lower	0	0	0	0	0	1	0	0	1
Lobectomy, right lower & middle	0	0	1	0	0	0	0	0	1
Lobectomy, right upper & middle	0	1	0	1	1	0	0	0	3
Lobectomy, left upper and sup. segment of lower	0	0	0	0	1	0	1	0	2
Totals	13	16	7	18	3	10	8	9	84
Operating time: 3-3:59 hr.	0	2	0	3	2	0	1	0	8
4-4:59 hr.	2	5	0	4	0	3	3	1	18
5-5:59 hr.	3	4	4	3	0	4	1	1	20
6-6:59 hr.	7	4	2	3	1	1	1	4	23
7-7:59 hr.	1	1	0	4	0	0	1	2	9
8-8:59 hr.	0	0	0	0	0	1	1	0	2
9-9:59 hr.	0	0	0	0	0	1	0	0	1
Totals	13	16	6	17	3	10	8	8	81
Operative and/or anesthetic difficulty	4	2	1	2	1	3	4	6	23
No especial difficulty	9	14	6	16	2	7	4	3	61
Totals	13	16	7	18	3	10	8	9	84
Blood loss: Under 1,000 c.c.	1	0	0	2	0	0	0	0	3
1,000 to 1,999 c.c.	3	2	2	5	0	3	1	1	17
2,000 to 2,999 c.c.	6	8	3	5	1	4	5	2	34
3,000 to 3,999 c.c.	3	4	1	1	1	2	2	3	17
4,000 to 4,999 c.c.	0	2	0	2	1	0	0	0	5
5,000 to 5,999 c.c.	0	0	0	0	0	0	1	0	1
6,000 to 6 999 c.c.	0	0	0	0	0	0	0	2	2

TABLE I.—CONT'D

	GOOD WORKING		SATISFACTORY WORKING		FAIR WORKING				
	YES	NO	YES	NO	YES	NO	POOR	DIED	TOTALS
7,000 to 7,999 c.c.	0	0	0	1	0	0	0	0	1
Totals	13	16	6	16	3	9	9	8	80
Preoperative hemoglobin: 64-79	5	2	1	4	1	6	1	5	25
80-89	5	9	2	10	1	1	6	0	34
90-100	3	4	3	2	1	2	1	2	18
Totals	13	15	6	16	3	9	8	7	77
Postoperative fever: 1- 5 days	0	0	0	1	1	2	0	1	5
(above 98.6° F.) 6-10 days	4	4	4	5	2	3	1	1	24
11-20 days	4	5	1	8	0	2	1	0	21
21-30 days	3	3	0	2	0	0	0	3	11
31-40 days	0	0	1	1	0	0	0	1	3
41 and over	1	3	0	1	0	0	0	1	6
Totals	12	15	6	18	3	7	2	7	70
Spreads one, first postoperative month	0	0	2	10	0	1	1	3	17
Spreads one, after first postoperative month	0	0	1	2	0	1	6	1	11
Spreads two or more, first month and later	0	0	0	0	0	2	1	2	5
No spreads	13	16	4	6	3	6	0	3	51
Totals	13	16	7	18	3	10	8	9	84
Bronchopleural fistula: first day	0	1	0	0	0	0	0	0	1
Bronchopleural fistula within 1 month	0	0	0	1	0	0	0	1	2
Bronchopleural fistula after first month	0	0	0	0	0	0	0	1	1
Totals	0	1	0	1	0	0	0	2	4
Postoperative sputums:									
All conc., cult., & gast. neg.	12	14	3	13	0	3	1	0	46
Neg. conc., cult. No gast. rep.	1	2	0	1	0	0	0	2	6
All conc., cult., gast. neg. except preceded by 1 pos. cult.	0	0	3	2	0	1	0	0	6
Neg. on conc., cult., gast. except preceded by occ. pos. culture	0	0	1	2	0	0	0	0	3
Neg. on conc., cult., gast. except preceded by occ. pos. conc.	0	0	0	0	0	1	0	2	3
Neg. conc.; occ pos. cult. or gastric	0	0	0	0	2	0	1	0	3
Neg. on conc., pos. on cult.	0	0	0	0	0	1	1	0	2
Neg. conc., occ. pos. culture	0	0	0	0	1	4	1	0	6
Occasional pos. concentrate	0	0	0	0	0	0	3	2	5
Regularly positive concen.	0	0	0	0	0	0	1	1	2
Totals	13	16	7	18	3	10	8	7	82

	TOTAL NUMBER OF CASES	GOOD AND SATISFACTORY	PERCENTAGE OF CASES WITH GOOD AND SATISFACTORY RESULTS
Males: Age 10-29	12	8	67
30-39	14	9	64
40 and over	15	10	67
Females: 10-29	17	11	65
30-39	14	6	43
40 and over	12	10	83
Race: White	32	23	72
Mexican	35	22	63
Negro	9	5	55
Other	8	4	50
Disease: Unilateral	4	4	100
Unilateral with cavity	6	5	83
Bilateral	33	21	64
Bilateral with unilateral cavity	41	24	58

TABLE I.—CONT'D

	TOTAL NUMBER OF CASES	GOOD AND SATISFACTORY	PERCENTAGE OF CASES WITH GOOD AND SATISFACTORY RESULTS
Cavity size: Under 2 cm.	22	16	73
Over 2 cm.	23	12	52
Cavity character: Slit	5	5	100
Bronchiectatic	7	5	71
Irregular	9	4	44
Round	8	5	62
Cavity location: Upper lobe	37	24	65
Lower lobe	9	5	55
Duration of disease: 0-1 yr.	9	6	67
2-4 yr.	20	13	65
5-9 yr.	35	24	68
10 and over	11	7	64
Preoperative sputum: Pos. Conc.	49	34	69
Preoperative neg. concentrate; pos. culture	32	19	60
Preoperative neg. concentrate; cult.; & gast.	3	3	100
Previous thoracoplasty:			
5 ribs or less	17	13	76
6 ribs or more	51	30	59
Type of Resection: Primary	16	11	69
Type: post thoracoplasty	68	43	63
Type primary resection:			
No thoracoplasty	8	7	88
Postresection thoracoplasty	8	4	50
Streptomycin: 5-39 Gm.	43	32	72
40 or more Gm.	38	21	55
Preop. bronchoscopy: no secretions	23	14	61
Preop. bronchoscopy: homolateral secretions	23	17	74
Preop. bronchoscopy: homolateral stenosis	18	11	61
Streptomycin resistant	16	6	38
Streptomycin not resistant	68	48	71
Previous tracheobronchial disease	23	14	61
No previous tracheobronchial disease	61	40	66
Operation: Pneumonectomy	56	35	63
Lobectomy	28	19	68
Operating time: Under 7 hours	69	46	67
Over 7 hours	12	6	50
Operative and/or anes. difficulty	23	9	39
No operative and/or anes. difficulty	61	45	74
Blood Loss: Under 3,000 c.c.	54	37	69
Over 3,000 c.c.	26	14	54
Preoperative hemoglobin under 80 per cent	25	12	48
over 80 per cent	52	38	73
Postoperative febrile course:			
1-10 days	29	18	62
over 10 days	41	33	80
Spreads: All types	33	15	45
No spreads	51	39	77
Bronchopleural fistulas	4	2	50

Fair: Some cases show an occasional positive sputum or gastric culture, yet remain fairly well. Others are completely negative on concentrate culture and gastric culture, but show slight residual infiltration; if a bronchopleural fistula was present, it is now closed. In this group there are thirteen cases, three of whom are now working, none full time.

Poor: These cases are not doing well. They show increase in disease, positive sputum, or bronchopleural fistula. Eight cases are in this group.

Deaths: There are nine deaths in this series, an over-all death rate of 10.7 per cent. There were two deaths within three days, each directly due to the surgery with an immediate surgical mortality rate of 2.4 per cent. The other deaths all occurred after four months.

The association of various factors with the results observed from one to four years after resection is shown in table form. From these figures the percentages of favorable results were calculated and significant relationships noted.

Review of Results.—Sex: Essentially no difference. *Age:* Little influence except in women over 40 years, who had best results. *Race:* Best in white race, next best in Mexicans, poorest in Japanese and Negroes. *Disease:* Unilateral disease far better results than bilateral disease. Cases with cavity less satisfactory results than those without cavity; but unilateral cavity cases did better than those with bilateral disease without cavity. *Cavity size:* Better results with small cavities, under 2 centimeters. *Cavity character:* Best results with slit and bronchiectatic cavities. All cases of slit cavity had a good result. *Cavity location:* No significant differences. *Duration of disease:* No significant differences. *Preoperative sputum:* Best results in the three cases who had negative sputum and gastric cultures. Cases with positive concentrates did better than those with negative concentrates and positive cultures.

The indications for resection in the three cases who were negative: (1) surgical emergency for hemoptysis. Previous four stages of thoracoplasty and revision; negative sputum since then. Left pneumonectomy. (2) Cavity in apex of left lung, seen on x-ray. Previous six rib thoracoplasty, negative sputum and gastric cultures since then. Left upper lobectomy. (3) Unexpandable diseased upper lobe. Pleural effusion and atelectatic lung with residual pneumothorax. Sputum and gastric cultures negative. Decorticated but upper lobe failed to expand. Left upper lobectomy.

Previous thoracoplasty: Best results with five ribs or less. *Type of resection:* Results best in resections not associated with thoracoplasty; but the primary resections followed by thoracoplasty did worse than those whose resection was preceded by thoracoplasty. *Streptomycin resistant:* Results almost twice as good in the cases who were not resistant to streptomycin, either partially or entirely. In the entire series this was one of the most outstanding findings.

Previous tracheobronchial disease: Results not significantly better in the cases who did not have previous disease. *Operation performed:* Results slightly better with lobectomy than with pneumonectomy, but difference not statistically significant. *Duration of operation:* Cases who required under seven hours did slightly better than those over seven hours. *Operative and/or anesthetic difficulties:* Results almost twice as good in the cases without difficulty. Most frequently encountered was difficulty in freeing the lung due to adhesions and adherence to the chest wall. *Blood loss:* Cases with blood loss under 3,000 c.c. did far better than those in which the loss was greater. Blood loss was generally greater in the cases in which difficulty in freeing the lung was present.

Preoperative hemoglobin: Cases with over 80 per cent did far better than those under 80 per cent. *Preoperative febrile course:* Until a case leveled off at 98.6° F. or under, that case was listed as having fever. Cases with febrile course over ten days did better than those under ten days. *Spreads:* Cases without spreads did far better than those with spreads. *Bronchopleural fistulas:* Two of the four cases with fistula had good results. One was immediately recognized so that closure was done within twenty-four hours; the other showed up four days after surgery and closed spontaneously within another week or so.

Significant hazards to obtaining a good result were:

1. Operative or anesthetic difficulties.
2. Resistance to streptomycin.
3. Spreads.
4. Bilateral disease.
5. Round or irregular cavity.
6. Cavity over 2 cm. in size.
7. Regular positive cultures or concentrates.
8. Preoperative hemoglobin under 80 per cent.
9. Blood loss over 3,000 c.c.
10. Previous six or more rib thoracoplasty.

Spreads: During the first postoperative month there were seventeen cases which had a spread. Any increase in pulmonary density was counted as a spread, although several cases so classified may have been due to atelectasis or hemorrhage into the bronchioles, since the x-ray shadow cleared rather rapidly.

Outcome of the seventeen spreads that occurred during the first postoperative month: Twelve cases showed complete clearing on radiographic examination and became completely negative on sputum and gastric cultures. Those cases were included in the satisfactory category. Three cases were classified as fair results; of these, one had a slight residual infiltration but became negative on sputum and gastric examinations. The second case had additional later spreads, but became negative on concentrate culture and gastric, but had residual soft infiltration. The third case had a later spread which completely cleared on x-ray examination, but the cultures were intermittently positive. Two cases were classified as poor; one developed a cavity and was intermittently positive on concentrate; the other had a later spread and was regularly positive on concentrate.

Of the thirty-three patients who had spreads, at any time following operation, one who developed soft infiltration and two who formed cavities died. Of the thirty surviving patients who had spreads, regression, fibrosis, or calcification has taken place in nineteen, but seven still have residual soft infiltration, and four others show definite cavitation.

Survivals: Of the seventy-five patients surviving in this series, sixty-four have no roentgenographic evidence of any soft infiltration, cavitation, or empyema, and are thus satisfactory results, from an x-ray standpoint. Four of

the seventy-five patients have positive concentrates, and eleven have positive cultures. Thus, 20 per cent still have positive sputums. Fifteen others were positive following resection, but are now negative. In addition to the obvious improvements in physical findings, roentgenogram, and laboratory data, many patients had marked lessening or disappearance of symptoms such as wheezing, anorexia, night sweats, coughing, and raising of sputum.

Review of Deaths.—1. White man, aged 36 years, streptomycin resistant, positive sputum, developed tuberculous meningitis four months after left pneumonectomy after previous thoracoplasty. He died three months later.

2. A Mexican man, aged 50 years, had positive sputum. He had a left pneumonectomy after a previous thoracoplasty. The operation required more than seven hours. The patient left the operating room in poor condition and died one hour later.

3. A Mexican woman, aged 19 years, had positive sputum and contralateral oleothorax. She had an extensive bronchopneumonic spread after a right pneumonectomy after a previous thoracoplasty. She died three days later.

4. A Mexican man, aged 19 years, had a bronchopleural fistula. He had a right pneumonectomy after a previous thoracoplasty. He subsequently had a spread and hydropneumothorax. He had a skin flap drainage; and he died seven months after resection.

5. A white woman, aged 59 years, had positive sputum. She ran an intermittent febrile course after a primary right pneumonectomy. She had a postresection thoracoplasty, and later had exploratory thoracotomy. She died eleven months after resection; autopsy showed widespread tuberculosis and right empyema.

6. A Negro man, aged 37 years, had a positive sputum. He had a left pneumonectomy after a previous thoracoplasty. He developed acute cor pulmonale and auricular fibrillation and died four months later.

7. A white man, aged 32 years, had a positive sputum. He died two years after a right pneumonectomy after a previous thoracoplasty. He had previously been discharged from Olive View; cause of death unknown.

8. A Negro man, aged 35 years, had a positive sputum. He had an early spread after left pneumonectomy after a previous thoracoplasty which completely regressed eighteen months after surgery. He was discharged and died on the outside two and three-fourths years after resection; cause of death unknown.

9. A Japanese woman, aged 31 years, had a positive sputum. She had a spread with cavity and hemoptysis, and died ten months after primary right pneumonectomy.

SUMMARY AND CONCLUSIONS

Of eighty-four resections for pulmonary tuberculosis at Olive View between 1947 and 1950, fifty-four gave satisfactory results, twenty-one unsatisfactory, and nine died. There was an immediate surgical mortality rate of 2.4 per cent, with an over-all death rate of 10.7 per cent. Follow-up of the seventy-five survivals one to four years later shows sixty with negative sputum, of whom

twenty-three are already working. Less satisfactory results were obtained in the Negro race, patients with larger or tension cavities, and in those already resistant to streptomycin. Poor results were also noted in patients who developed postoperative spreads and in those who required more chemotherapy or post-resection thoracoplasty.

Pulmonary resection is a valuable therapeutic measure in selected cases of pulmonary tuberculosis, especially for lesions which have not been controlled by thoracoplasty. Pulmonary resection should not be lightly undertaken. Careful selection and preparation of patients, meticulous surgical technique and painstaking postoperative care are required to minimize its dangers and insure maximum results.

SIX-FINGERED GLOVE FOR MITRAL COMMISSUROTOMY

EDWARD R. MUNNELL, M.D.
DETROIT, MICH.

OPERATIONS for mitral stenosis involving the insertion of a forefinger into the left auricle by way of its appendage have resulted in dramatic improvement in many patients.[1-4] While the finger is in the heart, hemostasis is usually easily obtained by the tightening of one or more purse-string ligatures previously placed around the base of the appendage. However, if attempts to open the valve by blunt dissection or "finger fracture" are unsuccessful, it becomes necessary to introduce some type of cutting instrument along the finger. With the high auricular pressure encountered in mitral stenosis, the presence of the instrument between the finger and the appendage wall may permit the escape of considerable amounts of blood. Bailey, Glover, and O'Neill described a technique to minimize this bleeding. A second glove was placed on the operator's hand, and the commissurotomy knife was passed through a slit in the palm and out through the amputated tip of the forefinger of the glove. Harken has used a part of a finger cot for this purpose. In fifteen mitral commissurotomies, Dr. Conrad Lam employed the two-glove technique and noted that there was frequently troublesome bleeding from the hole in the outer glove from which the knife emerged. In one patient there was post-commissurotomy hypotension apparently due to excessive blood loss, and in others it was necessary to make hasty decisions as to the adequacy of the incisions into the commissures.

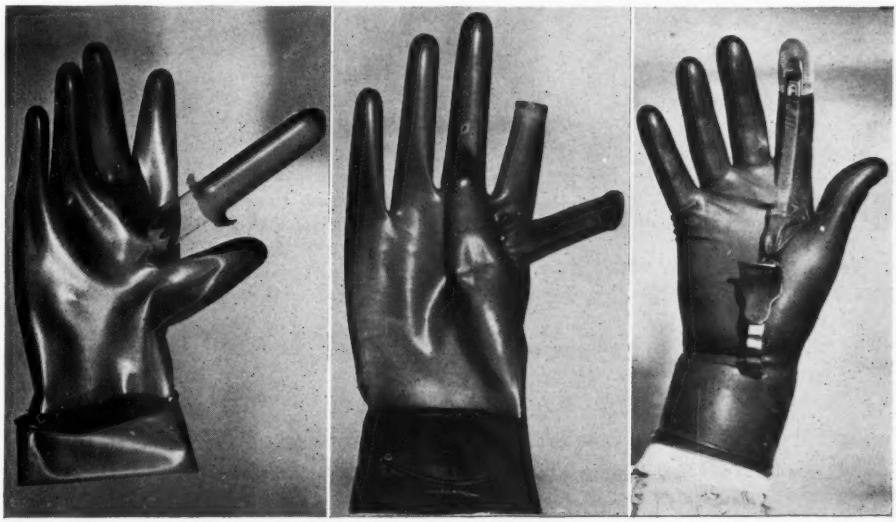
The six-fingered glove was designed to obviate this remaining source of hemorrhage. The use and advantages of this glove have been mentioned in a previous paper.[5] It has now been used by Dr. Lam in twenty additional cases. It has reduced blood loss to negligible amounts, and has enabled the surgeon to explore and incise the stenotic mitral valve without urgency. The purpose of this communication is to describe the construction of the glove for the benefit of others who may feel the need of it.

The third finger of a surgical glove is removed at its base, taking liberal margins from the palmar and dorsal surfaces of the glove (Fig. 1, *A*). This is then placed over a test tube which the rubber finger will fit snugly. A star is then cut in the recipient glove on the palmar surface approximately halfway between the thenar eminence and the index finger. The finger to be added and test tube are inserted through the star to the desired position. The rubber in the region of apposition is cleaned with benzene and cemented with several

From the Division of General Surgery of the Henry Ford Hospital.
Received for publication Dec. 10, 1951.

layers of rubber cement.* Excess rubber at the base of the sixth finger is removed; the tips of the added finger and the index finger are cut off and small cuffs are turned and cemented (Fig. 1, *B*). The glove is placed in an oven at 200° F. for half an hour, after which the test tube is removed and the glove is tested for leaks. It is then packaged and autoclaved in the usual manner.

The six-fingered glove is employed in commissurotomy after the purse-string ligatures are placed in the base of the auricular appendage and the tip of the appendage is amputated distal to a noncrushing clamp. The glove is put on over the standard operating glove. The guillotine knife is moistened in saline and slipped through the added "sixth" finger and out the index



A. *B.* *C.*

Fig. 1.—Six-fingered glove for use in mitral commissurotomy: *A*, Method of adding sixth finger to glove. *B*, Completed glove. *C*, Use of the glove with the new model "push" type of Bailey-Glover-O'Neill commissurotomy guillotine. Note that the glove is applied over the usual surgical glove and the guillotine knife is inserted through the sixth finger and out the index finger. A ligature fastens the sixth finger securely to the knife.

finger. The end of the sixth finger which has become an instrument tunnel is then closed tightly with two turns of a heavy silk ligature (Fig. 1, *C*). With the forefinger and instrument in the auricle, blood flows into the extra finger and space between the two gloves, but can go no further. Occasionally with very high auricular pressures it has been necessary to place a tape ligature around the operator's wrist to close that avenue of escape.

SUMMARY

A six-fingered glove for the further prevention of hemorrhage during mitral commissurotomy has been described.

*John Bunn Corporation, Buffalo, N. Y.

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NIXON, J. W.---1131 Nix Professional Bldg., San Antonio, Texas

O'BRIEN, EDWARD J.---307 David Whitney Bldg., Detroit 26, Mich.
OATWAY, WILLIAM H., JR.---LaVina Sanatorium, Altadena, Calif.
OCHSNER, ALTON---Tulane University School of Medicine, Department of Surgery, New Orleans, La.
O'ROURKE, PAUL V.---307 David Whitney Bldg., Detroit, Mich.
OVERHOLT, RICHARD H.---1101 Beacon St., Brookline, Mass.

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ROGERS, W. L.—490 Post St., San Francisco, Calif.
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ROSS, DUDLEY E.—974 Dunsmuir Road, Mount Royal, Que.
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SAMSON, PAUL C.—2938 McClure St., Oakland 9, Calif.
SANGER, PAUL W.—1518 Harding Place, Charlotte, N. C.
SCANNELL, J. GORDON—Massachusetts General Hospital, Boston, Mass.
SCHAFFNER, VERNON D.—Kentville, Nova Scotia
SHAW, ROBERT R.—3810 Swiss Ave., Dallas, Texas
SHEFTS, LAURENCE M.—503 Moore Bldg., San Antonio, Texas
SHUMACKER, HARRIS B., JR.—Indiana University Medical Center, Indianapolis, Ind.
SKINNER, EDWARD F.—899 Madison Avenue, Memphis, Tenn.
SKINNER, GEORGE F.—36 Coburg St., St. John, N. B.
SLOAN, HERBERT F.—1225 Kensington Dr., Ann Arbor, Mich.
SOMMER, GEORGE N. J. JR.—120 W. State St., Trenton, N. J.
SOUTTER, LAMAR—205 Beacon St., Boston, Mass.
STEELE, J. D.—1705 W. Wisconsin Ave., Milwaukee, Wis.
STEPHENS, H. BRODIE—384 Post St., San Francisco, Calif.
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SWAN, HENRY, II.—410 Marion St., Denver, Colo.
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THOMPSON, SAMUEL A.—850 Park Ave., New York, N. Y.
TOUROFF, ARTHUR S. W.—994 Fifth Ave., New York 28, N. Y.
TUTTLE, WILLIAM M.—307 David Whitney Bldg., Detroit 26, Mich.
TYSON, M. DAWSON—Hitchcock Clinic, Hanover, N. H.

VAN HAZEL, WILLARD—224 S. Michigan Blvd., Chicago, Ill.
VARCO, RICHARD L.—Dept. of Surgery, University of Minnesota, University Hospital, Minneapolis, Minn.
VINEBERG, ARTHUR M.—1108 Elgin Terrace, Apt. 101, Pell St., Montreal, Que.

WANGENSTEEN, OWEN H.—University Hospital, Minneapolis, Minn.
WATERMAN, DAVID H.—607 Medical Arts Bldg., Knoxville, Tenn.
WATSON, WILLIAM LAW—1088 Park Ave., New York, N. Y.
WEINBERG, JOSEPH A.—Veterans Administration Hospital, Long Beach, Calif.
WELLES, EDWARD S.—110 Park Ave., Saranac Lake, N. Y.
WHITE, MARION LAWRENCE, JR.—First Huntington Nat. Bank Bldg., Huntington, W. Va.
WILLIAMS, MARK H.—63 Front St., Binghamton, N. Y.
WILSON, NORMAN J.—1101 Beacon St., Brookline, Mass.
WOODRUFF, WARRINER—8 Church St., Saranac Lake, N. Y.
WOODS, FRANCIS M.—1101 Beacon St., Brookline, Mass.
WRIGHT, GEORGE WILBUR—103 Park Ave., Saranac Lake, N. Y.
WYLIE, ROBERT H.—535 Park Ave., New York, N. Y.

Associate Members

ACKMAN, F. DOUGLAS—1374 Sherbrooke St., W., Montreal, Que.
AITCHISON, DAVID BANCROFT—Mount Sanatorium, Hamilton, Ont.
ASHBURN, FRANK S.—1835 Eye St., N.W., Washington, D. C.
AUERBACH, OSCAR—121 Hamden Ave., Staten Island, N. Y.

BADGER, THEODORE I.—264 Beacon St., Boston, Mass.
BEECHER, HENRY K.—Massachusetts General Hospital, Boston 14, Mass.
BENEDICT, EDWARD BENSON—Massachusetts General Hospital, Boston 14, Mass.
BORTONE, FRANK—2765 Hudson Blvd., Jersey City, N. J.
BOSHER, LOUIS H.—Medical College of Virginia Hospital, 1200 E. Broad Street, Richmond, Va.
BOYD, DAVID P.—605 Commonwealth Ave., Boston, Mass.
BRINDLEY, GEORGE VALTER, JR.—Scott and White Clinic, Temple, Texas
BROWN, ROBERT K.—806 Metropolitan Bldg., Denver, Colo.
BROWNRIGG, GARRETT M.—47 Queens Rd., St. Johns, Newfoundland
BRUNEAU, JACQUES—847 Cherrier, Montreal 24, Que.
BURBANK, BENJAMIN—244 Henry St., Brooklyn 2, N. Y.

CARSWELL, JAMES, JR.—Veterans Administration Hospital, McKinney, Texas
CARTER, MAX G.—614 Orange St., New Haven, Conn.
CHANDLER, JOHN HUGHES—420 E. Main St., Jackson, Tenn.
CHODOFF, RICHARD JOSEPH—1823 Pine St., Philadelphia, Pa.
CHUNN, CHARLES FRANCIS—442 W. Lafayette St., Tampa 6, Fla.
CHURCHILL, AMBROSE SEVIER—524 West "G" St., San Diego, Calif.
CONDON, WILLIAM B.—1008 Republic Bldg., Denver, Colo.
COOPER, DAVID A.—1520 Spruce St., Philadelphia, Pa.
COX, WILLIAM V.—133 Court St., Auburn, Maine
CRACOVANER, ARTHUR J.—114 East 72nd St., New York, N. Y.
CRANDELL, WALTER B.—Veterans Administration Hospital, White River Junction, Vt.
CRECCA, ANTHONY DANIEL—376 Roseville Ave., Newark 7, N. J.
CUTLER, PRESTON R.—807 Medical Arts Bldg., Salt Lake City 1, Utah

DAFOE, COLIN S.—11037 80th Ave., Edmonton, Alberta
DAILEY, JAMES E.—3214 Reba Drive, Houston, Texas
DAVISON, RICHARD—5300 N. Christian Ave., Chicago 13, Ill.
DECAMP, PAUL TRUMBULL—1835 General Pershing, New Orleans, La.
DENNIS, CLARENCE E.—State University Medical Center, King's County Hospital, 451 Clarkson Ave., Brooklyn 3, N. Y.
DESHAIES, GEORGES—37 Bellingham Road, Montreal, Que.
DETERLING, RALPH A., JR.—180 Ft. Washington Ave., New York, N. Y.
DODDS, G. ALFRED—807 Broadway, Fargo, N. D.
DOMM, SHELDON E.—605 W. Main Ave., Knoxville, Tenn.
DRAKE, EMERSON H.—29 Deering St., Portland, Maine

EGLEE, EDWARD P.—105 East 53rd St., New York, N. Y.
EHRENHAFT, JOHANN L.—University of Iowa, Iowa City, Iowa
ELLISON, ROBERT G.—University Hospital, Augusta, Ga.
EVANS, BYRON HENRY—2918 Fresno St., Fresno, Calif.

FALOR, WILLIAM H.—623 Second National Bldg., Akron 8, Ohio
FINNEY, GEORGE G.—2947 St. Paul Street, Baltimore, Md.
FISCHER, WALTER W.—3 East 71st St., New York 21, N. Y.
FISHBACK, FREDERICK C.—1835 Eye St., N.W., Washington, D. C.
FORD, WILLIAM B.—1107 Clark Bldg., Pittsburgh 22, Pa.
FRANK, HOWARD A.—330 Brookline Ave., Boston 15, Mass.
FRIEDLANDER, RALPH—Veterans Administration Hospital, Brooklyn, N. Y.

GAENSLER, EDWARD A.---249 River St., Mattapan 26, Mass.
GAGNON, EDOUARD DONAT---3411 St. Denis St., Montreal, Que.
GEARY, PAUL---909 Park Ave., Plainfield, N. J.
GOLDMAN, ALFRED---416 N. Bedford Drive, Beverly Hills, Calif.
GORDON, JOSEPH---New York State Tuberculosis Hospital, Ray Brook, N. Y.
GRACE, EDWIN J.---121 Fort Green Place, Brooklyn, N. Y.
GRISWOLD, R. A.---323 E. Chestnut St., Louisville, Ky.
GUPTILL, PLIMPTON---16 N. Goodman St., Rochester, N. Y.

HAMPTON, FOSTER, JR.---Hogshead Apts., Chattanooga, Tenn.
HARRISON, ELLIOTT---925 W. Georgia St., Vancouver, B. C.
HELMSWORTH, JAMES A.---Cincinnati General Hospital, Cincinnati, Ohio
HERBEN, GEORGE F.---House of Rest at Sprain Ridge, Yonkers, N. Y.
HEROY, WILLIAM W.---22 Oakwood Road, Huntington, N. Y.
HERRERRA-LLERANDI, RODOLFO E.---7-A Avenida Sur 18, Guatemala City, Guatemala
HIGGINSON, JOHN F.---2455 N.W. Marshall St., Portland, Ore.
HOCHBERG, LEW A.---135 Eastern Parkway, Brooklyn 17, N. Y.
HOLLINGSWORTH, RUSSELL K.---Baker V. A. Hospital, Martinsburg, W. Va.
HOPKINS, WILLIAM A.---1374 Villa Drive, Atlanta, Ga.
HUDSON, THEODORE R.---55 E. Washington St., Chicago, Ill.
HUN, HENRY---149 Washington Ave., Albany, N. Y.
HURLEY, G. A. PATRICK---3001 Kent Ave., Montreal, Que.
HURWITZ, ALFRED---Veterans Administration Hospital, Newington, Conn.

INGRAM, IVAN N.---909 Hyde St., San Francisco, Calif.
IOVINE, VINCENT M.---1150 Connecticut Ave., N.W., Washington, D. C.

JARVIS, FRED J.---900 Boylston Ave., Seattle, Wash.
JOHNSON, ELGIE K.---909 President St., Brooklyn, N. Y.
JOHNSON, HOLLIS E.---2122 West End Ave., Nashville, Tenn.
JOHNSTON, JAMES H., JR.---727 Carlisle St., Jackson, Miss.
JOYNT, G. H. C.---170 St. George St., Toronto, Ont.
JUDD, ARCHIBALD R.---304 N. Fourth St., Hamburg, Pa.

KELLY, WINFIELD O.---Uncas on Thames, Norwich, Conn.
KESSLER, CHARLES R.---Suite 1027, Woodward Bldg., Birmingham 3, Ala.
KING, CHARLES R.---814 Doctors Bldg., Atlanta, Ga.
KIPP, HAROLD A.---Mercy Hospital, Pittsburgh, Pa.
KIRBY, CHARLES KEELING---3400 Spruce St., Philadelphia, Pa.
KLEPSER, ROY GEORGE---Suite 501, 1835 Eye St., N.W., Washington, D. C.
KLOPSTOCK, ROBERT---Triboro Hospital, Jamaica, N. Y.
KUNDERMAN, PHILLIP JOHN---165 Livingston Ave., New Brunswick, N. J.
KUNSTLER, WALTER E.---5238 Queen Mary Road, Montreal, Que.

LAMPSON, RUTLEDGE STARR---85 Jefferson St., Hartford, Conn.
LAUREY, JAMES R.---1318 Girard St., N.W., Washington, D. C.
LAWRENCE, EDWIN A.---Dept. of Surgery, Indiana University Medical Center, Indianapolis, Ind.
LEES, WILLIAM MORRIS---30 N. Michigan, Chicago, Ill.
LEETCH, HENRY W.---108 Main St., Saranac Lake, N. Y.
LEWIS, RUBIN M.---2380 Ellsworth, Berkeley, Calif.
LONGACRE, JACOB JAMES---1503 Carew Tower, Cincinnati, Ohio
LYON, CLAYTON---384 Post St., San Francisco, Calif.

MACDONALD, NEIL---Medical Arts Bldg., Windsor, Ont.
MACKLER, SAUL ALLEN---104 S. Michigan Ave., Chicago 3, Ill.
MACMANUS, JOSEPH---491 Delaware, Buffalo, N. Y.

MACPHERSON, LACHLAN—St. John Tuberculosis Hospital, East St. John, N. B.
MADER, VICTOR O.—149 S. Park St., Halifax, Nova Scotia
MASON, JAMES MONROE III.—1023 South 20th St., Birmingham, Ala.
MAYER, JOHN HENRY, JR.—829 West 55th St., Kansas City, Mo.
MERENDINO, A. A.—University of Washington, Seattle, Wash.
MICHELSON, ELLIOTT—1801 Eutaw Place, Baltimore, Md.
MIDELFART, PETER A.—321 Summit Ave., Eau Claire, Wis.
MILLER, CARROL C.—1265 Beacon St., Brookline 46, Mass.
MILLER, FELIX P.—109 N. Oregon St., El Paso, Texas
MILLS, WALDO O.—437 Stimson Bldg., Seattle 1, Wash.
MINOR, GEORGE R.—University of Virginia Hospital, Charlottesville, Va.
MOUSEL, LLOYD H.—Dept. of Anesthesiology, The Swedish Hospital, Seattle, Wash.
MULLER, WM. H., JR.—School of Medicine, U.C.L.A., Los Angeles 24, Calif.

OLSEN, ARTHUR M.—102 2nd Ave., S.W., Rochester, Minn.
O'NEILL, JAMES F.—32 Roslyn Avenue, Glenside, Pa.
O'NEILL, THOMAS J.—269 South 19th St., Philadelphia 3, Pa.

PARKER, EDWARD F.—70 Hasell St., Charleston, S. C.
PHILLIPS, FRANCIS J.—Seward Sanatorium, Seward, Alaska
PINKHAM, ROLAND DAVIS—1106 Cobb Bldg., Seattle, Wash.
POLLOCK, WILLIAM C., COL. M.C., U.S.A.—1336 Cherry St., Denver 8, Colo.
POPPE, J. KARL—1130 S.W. Morrison St., Portland, Ore.
POTTER, BENJAMIN P.—Chest Division, Medical Center, Jersey City, N. J.
PRATT, LAWRENCE ARTHUR—Suite 800, Doctors Bldg., 3919 John R. St., Detroit, Mich.

RAMSAY, BEATTY H.—12300 Wilshire Blvd., Los Angeles 25, Calif.
RASMUSSEN, RICHARD ALLEN—Blodgett Medical Bldg., Grand Rapids, Mich.
READ, CHARLES T.—926 E. McDowell Rd., Phoenix, Ariz.
RICHARDS, VICTOR—Stanford-Lane Hospital, San Francisco 15, Calif.
RYAN, THOMAS C.—2033 S. Lincoln St., Oceanside, Calif.

SANES, GILMORE M.—3500 Fifth Ave., Pittsburgh 13, Pa.
SCHAFER, PAUL W.—University of Kansas Medical Center, Kansas City, Kan.
SCHMIDT, HERBERT WM.—Mayo Clinic, Rochester, Minn.
SCOTT, HENRY W., JR.—Vanderbilt University Hospital, Nashville, Tenn.
SEALY, WILL C.—Duke University Hospital, Durham, N. C.
SELEY, GABRIEL PARKUST—39 East 61st St., New York, N. Y.
SEYBOLD, WILLIAM DEMPSEY—Hermann Professional Bldg., Texas Medical Center, Houston, Texas
SHIPMAN, SIDNEY—490 Post St., San Francisco, Calif.
SIMPSON, H. MURRAY—292 Queen's Ave., London, Ont.
SKINNER, A. M.—Homer Folks Tuberculosis Hospital, Oneonta, N. Y.
SNYDER, HOWARD ERROL—103½ E. Ninth Ave., Winfield, Kan.
STENSTROM, JOHN D.—2390 Bowker Ave., Victoria, B. C.
STOREY, CLIFFORD F., CAPT., M.C.,—U. S. Naval Hospital, St. Albans, N. Y.
STRANAHAN, ALLAN—Albany Hospital, Albany, N. Y.
STRODE, JOSEPH E.,—The Clinic, 1021 Kapiolani, Honolulu, T.H.
SULLIVAN, HERBERT J.—58 Wellington St., South, Hamilton, Ont.
SWENSON, ORVAR—300 Longwood Ave., Boston, Mass.

TERRILL, FRANK I.—Montana State Tuberculosis Sanatorium, Route 1 Deer Lodge, Mont.
TEST, FREDERICK C., II.—91 Cass Ave., Mount Clemens, Mich.
THORNTON, THOMAS F., JR.,—309 Allen St., Waterloo, Iowa
TILLOU, DONALD J.—311 W. Church St., Elmira, N. Y.

VEAL, J. ROSS—3560 Appleton St., N.W., Washington, D. C.
VORWALD, ARTHUR J.—Director of Research, Trudeau Foundation, 7 Church St., Saranac Lake, N. Y.

WALKER, JAMES H.—1101 Beacon St., Brookline, Mass.
WEISEL, WILSON—324 E. Wisconsin Ave., Milwaukee 2, Wis.
WHITESIDE, WILLIAM CARLETON—342 Birks Bldg., Edmonton, Alberta
WILLAUER, GEORGE—1930 Chestnut St., Philadelphia, Pa.
WILSON, JULIUS LANE—Henry Phipps Institute, Philadelphia, Pa.
WIPER, THOMAS B.—536 Mason St., San Francisco, Calif.

Senior Members

ALLEN, DUFF S.—Washington University Medical School, St. Louis, Mo.
AMBERSON, J. B.—Bellevue Hospital, New York, N. Y.

BALLON, DAVID—1538 Sherbrooke St., N. Montreal 25, Que.
BAZIN, A. T.—1414 Drummond St., Montreal, Que.
BERRY, FRANK B.—71 East 71st St., New York, N. Y.
BETTMAN, RALPH B.—104 S. Michigan Ave., Chicago, Ill.
BIGGER, ISAAC A.—Medical College of Virginia, Richmond, Va.
BOLAND, FRANK K.—478 Peachtree St., N.E., Atlanta, Ga.
BUTLER, ETHAN FLAGG—956 West Water Street, Elmira, N. Y.
BYERS, H. RODDICK—3166 Westmont Blvd., Montreal, Que. (Mail Returned)

CARLSON, HERBERT A.—4241 East 14th St., Long Beach, Calif.
CARTER, B. NOLAND—Cincinnati General Hospital, Cincinnati, Ohio
CHURCHILL, EDWARD D.—Massachusetts General Hospital, Boston, Mass.
CLERF, LOUIS H.—1530 Locust St., Philadelphia, Pa.
COLE, DEAN B.—Professional Bldg., Richmond, Va.
CROWE, SAMUEL J.—Johns Hopkins Hospital, Baltimore, Md.

DAVISON, T. C.—478 Peachtree St., N.E., Atlanta, Ga.
DIEDERICH, VICTOR—236 Central Ave., Hot Springs, Ark.
DIEFFENBACH, RICHARD H.—570 Mt. Prospect Ave., Newark 4, N. J.
DOVELL, CHAUNCEY D., COL. M.C., U.S.A.—Regional Hospital, Fort Sheridan, Ill.

EGGERS, CARL—850 Park Ave., New York, N. Y.
EINHORN, MAX—20 East 63rd St., New York, N. Y.
ELKIN, DANIEL C.—Emory University Hospital, Atlanta, Ga.
ELOESSER, LEO—490 Post St., San Francisco, Calif.

FAULKNER, WILLIAM B., JR.—1796 Geary St., San Francisco, Calif.
FERGUSON, R. G.—Fort San, Sask.
FRANK, LOUIS WALLACELL—614 Heyburn Bldg., Louisville, Ky.

GRAHAM, EVARTS A.—Barnes Hospital, St. Louis 10, Mo.

HARRINGTON, STUART W.—Mayo Clinic, Rochester, Minn.
HARVEY, SAMUEL C.—New Haven Hospital, New Haven, Conn.
HAYES, JOHN N.—24 Church St., Saranac Lake, N. Y.
HEINBECKER, PETER—Washington University Medical School, St. Louis, Mo.

JOHNS, FRANK S.—Johnston-Willis Hospital, Richmond, Va.

KERNAN, JOHN D.—103 East 78th St., New York, N. Y.
KING, DONALD S.—Massachusetts General Hospital, Boston, Mass.

LAMBERT, ADRIAN, V.S.---122 East 76th St., New York, N. Y.
LEMON, WILLIS S.---510 Tenth Ave., S.W., Rochester, Minn.
LEWALD, LEON T.---1200 Fifth Ave., New York, N. Y.
LOCKWOOD, A. L.---300 Bloor St., E. Toronto, Ont.

MAES, URBAN---Pontchartrain Hotel, New Orleans, La.
MCSWEENEY, E. S.---102 East 35th St., New York, N. Y. (Mail Returned)
MILLER, ROBERT T., JR.---Mountain Lake, Lake Wales, Fla.
MYERS, J. ARTHUR---730 LaSalle Bldg., Minneapolis, Minn.

NEUHOF, HAROLD---1200 Fifth Ave., New York 29, N. Y.

ORNSTEIN, GEORGE---965 Fifth Ave., New York, N. Y.

PACKARD, EDWARD N.---142 Park Ave., Saranac Lake, N. Y.
PICKHARDT, OTTO C.---66 East 79th St., New York, N. Y.

RIGLER, LEO G.---University Hospital, Minneapolis, Minn.

SHIPLEY, ARTHUR M.---University Hospital, Baltimore, Md.
SINGER, J. J.---616 N. Crescent Drive, Beverly Hills, Calif.
SMITH, DAVID T.---Duke University, Durham, N. C.
STEWART, GEORGE A.---3301 N. Charles St., Baltimore, Md.

THEARLE, WILLIAM H.---221 W. Central Ave., Albuquerque, N. Mex.
THORBURN, GRANT---1602 West Genessee St., Flint, Mich.
TUCKER, GABRIEL---250 South 19th St., Philadelphia, Pa.

VAN ALLEN, CHESTER M.---State Hospital, Bikaner, Rajputana, India

WHITTEMORE, WYMAN---Boyce, Va.

Members Deceased

ADRIAN A. EHLER
DEWITT STETTEN
LAWRENCE W. NEHIL

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